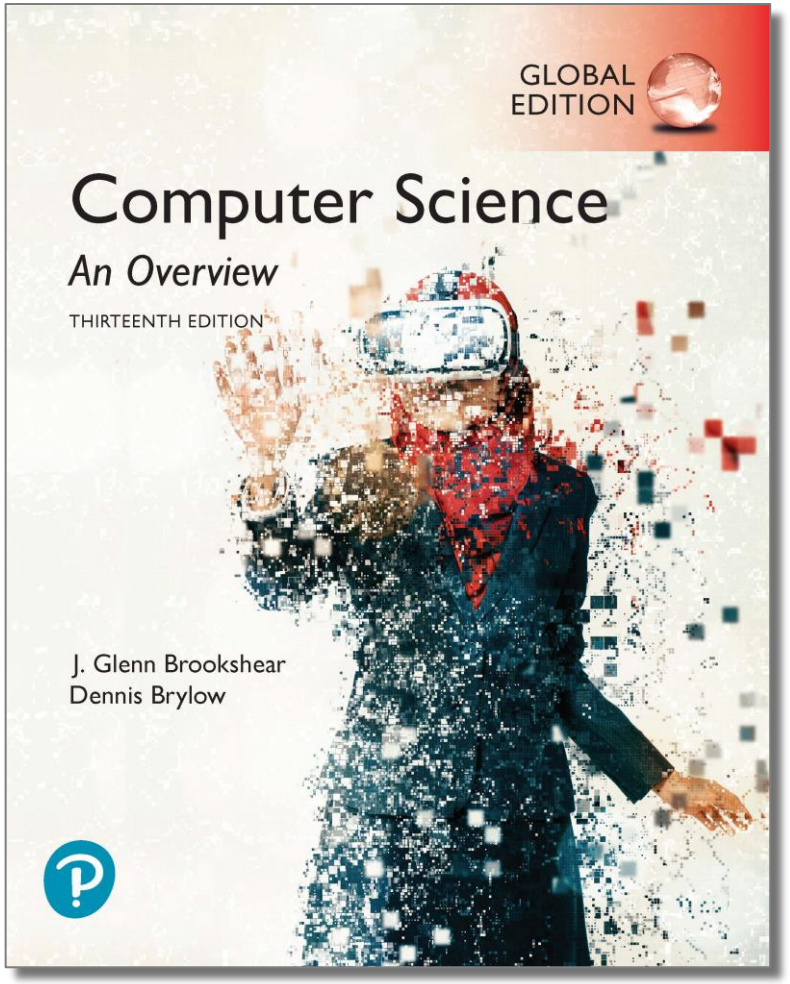
Computer Science An Overview

13th Edition, Global Edition



Chapter 6

Programming Languages

Chapter 6: Programming Languages

- 6.1 Historical Perspective
- 6.2 Traditional Programming Concepts
- 6.3 Procedural Units
- 6.4 Language Implementation
- 6.5 Object Oriented Programming
- 6.6 Programming Concurrent Activities
- 6.7 Declarative Programming

6.1 Historical Perspective

- Early Generations
  - Machine Language (e.g. Vole)
  - Assembly Language
- Machine Independent Language
- Beyond – more powerful abstractions

High-level language program (in C)

```
swap(int v[], int k)
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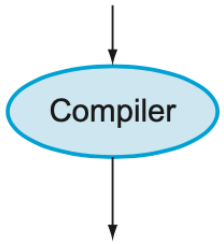

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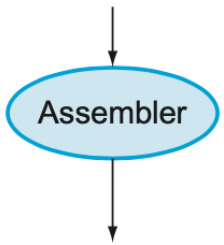

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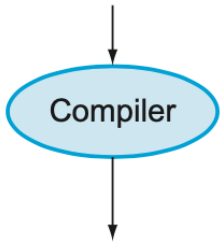

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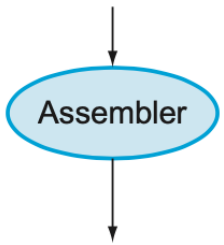

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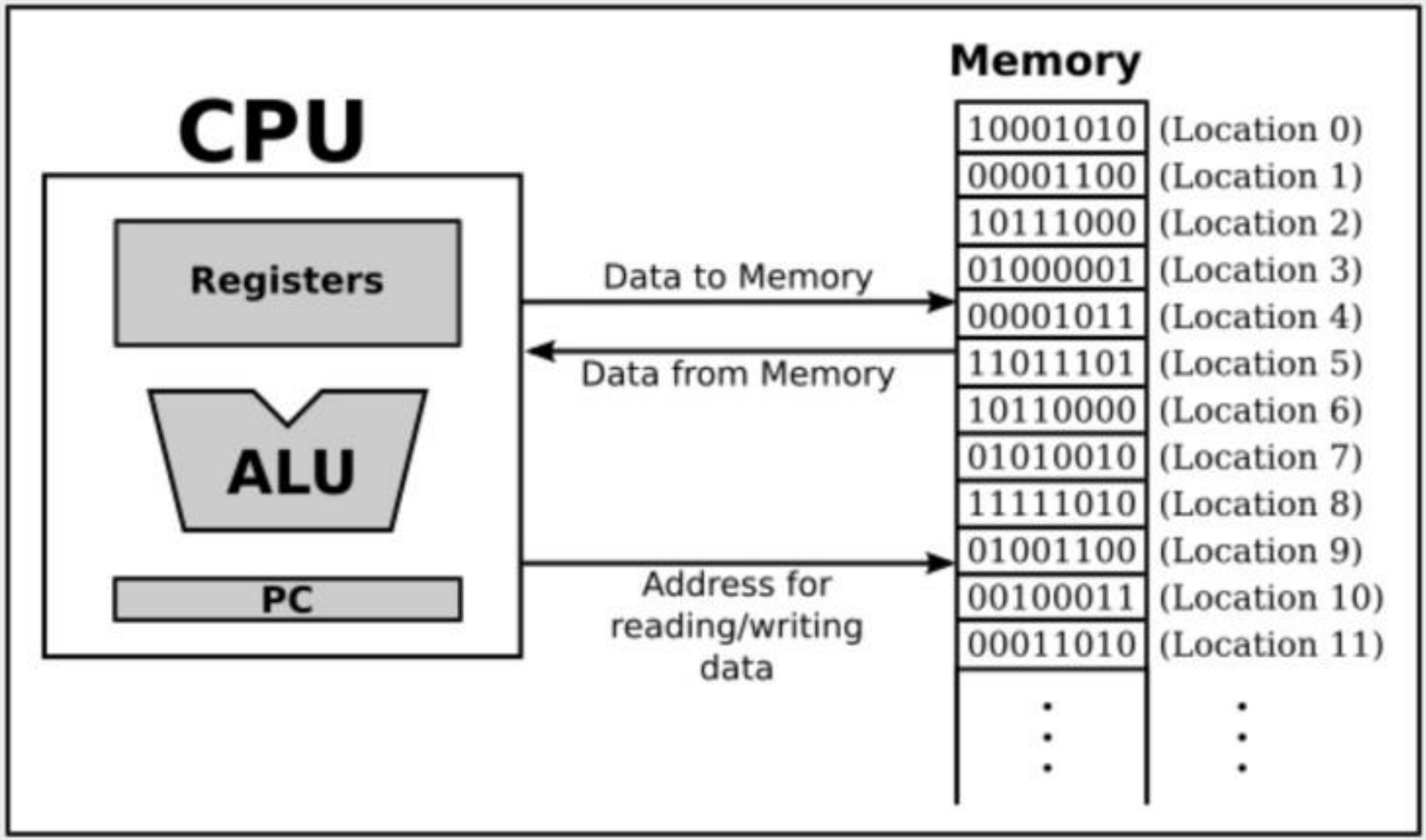

https://sciencesoftcode.wordpress.com/2020/08/14/programming-1-java/

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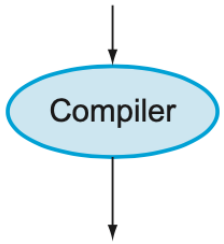

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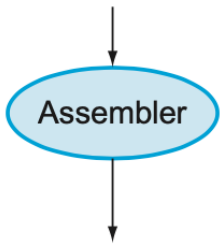

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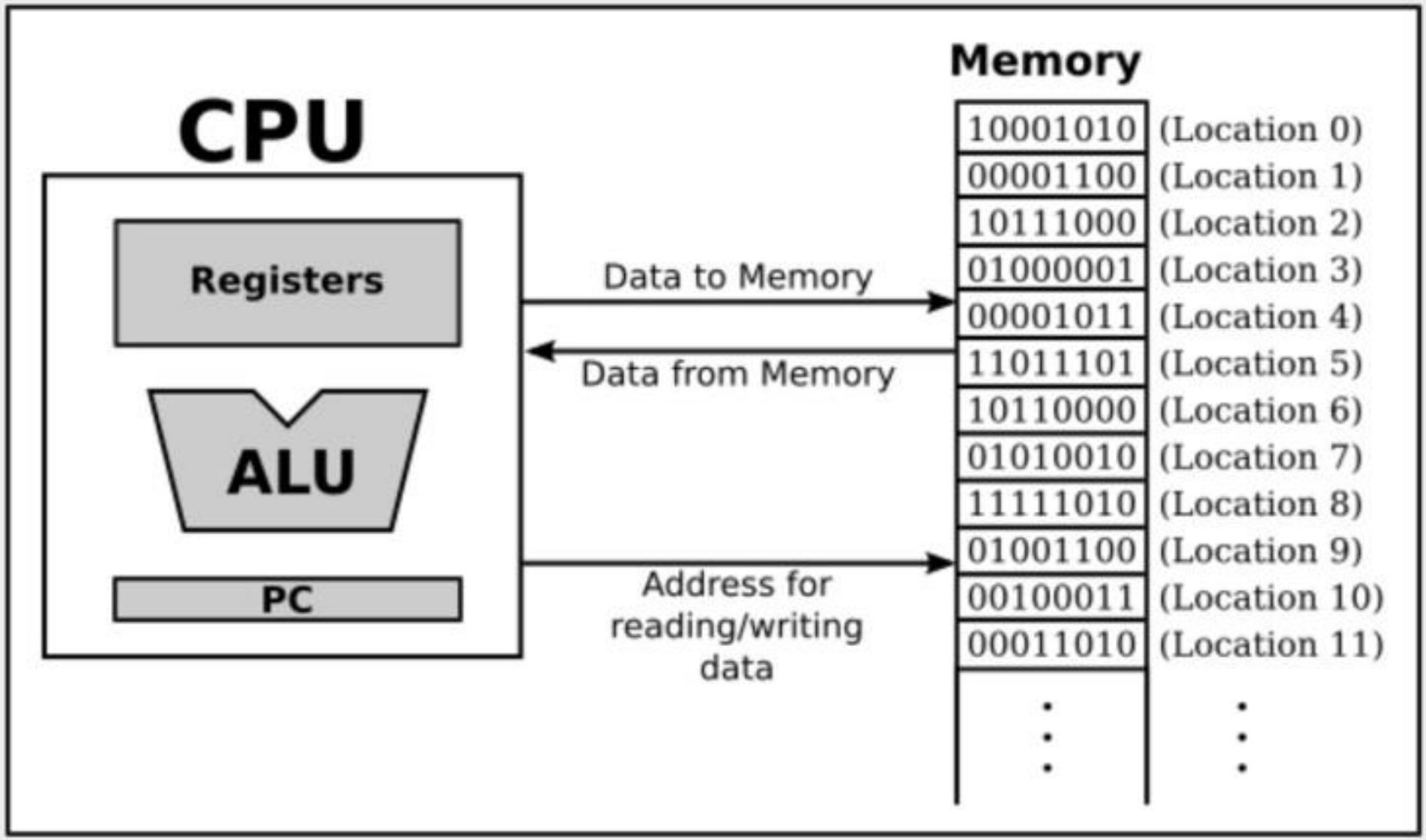

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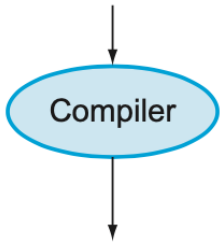

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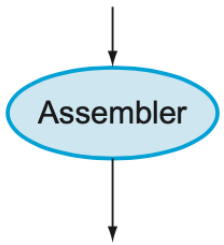

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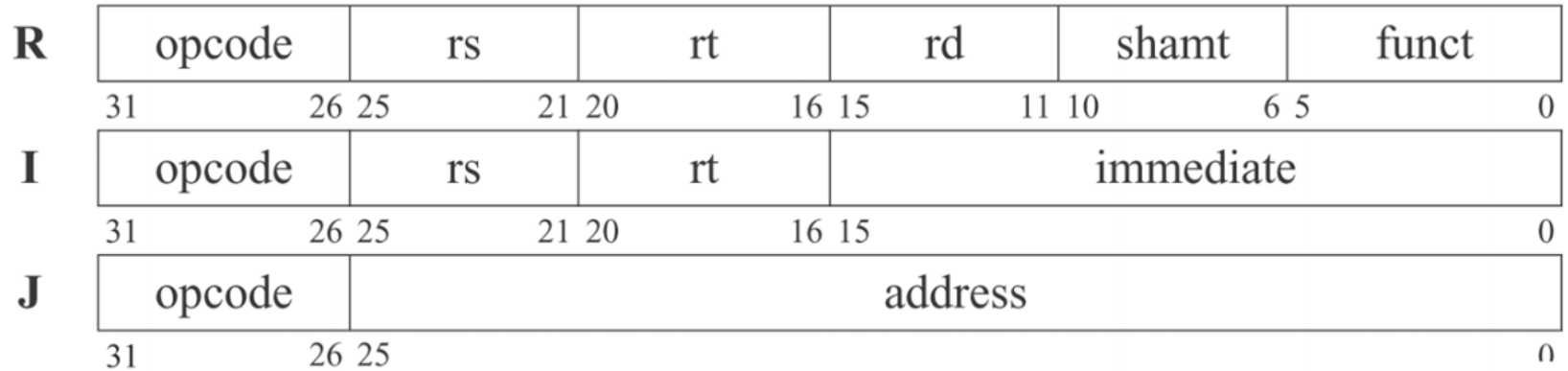
Second-generation: Assembly language

- A mnemonic system for representing machine instructions
  - Mnemonic names for op-codes
  - Program **variables** or **identifiers**: Descriptive names for memory locations, chosen by the programmer

BASIC INSTRUCTION FORMATS



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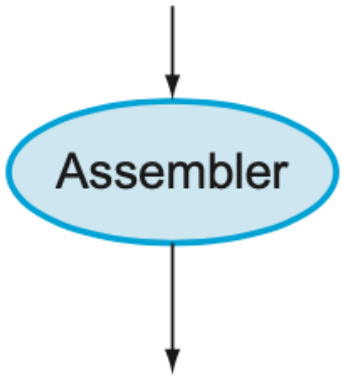

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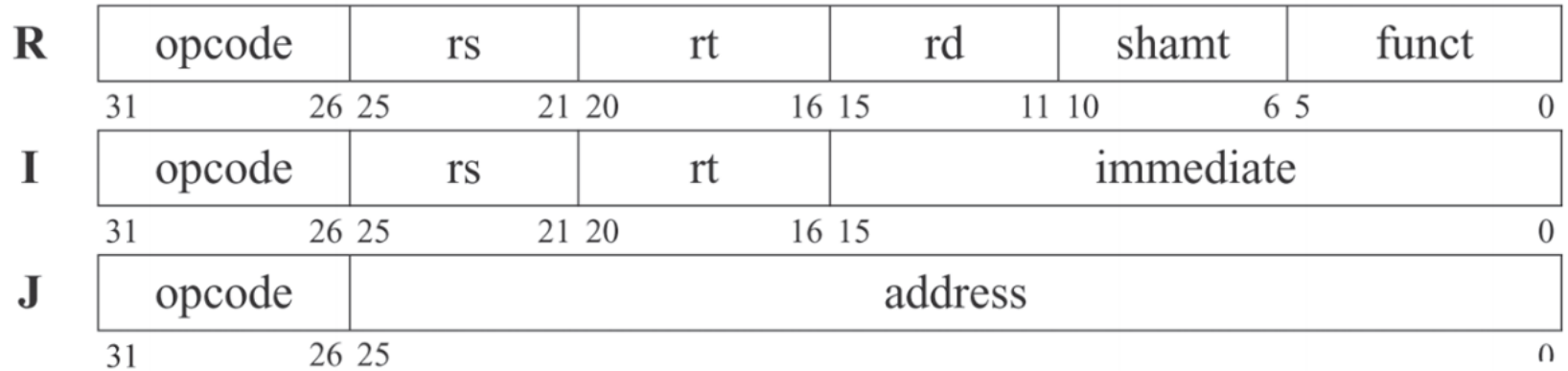

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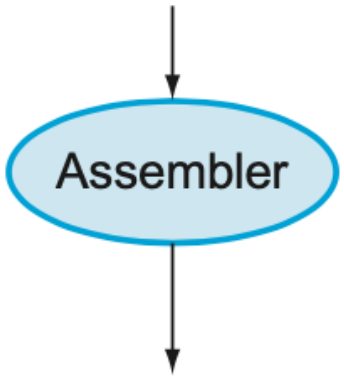

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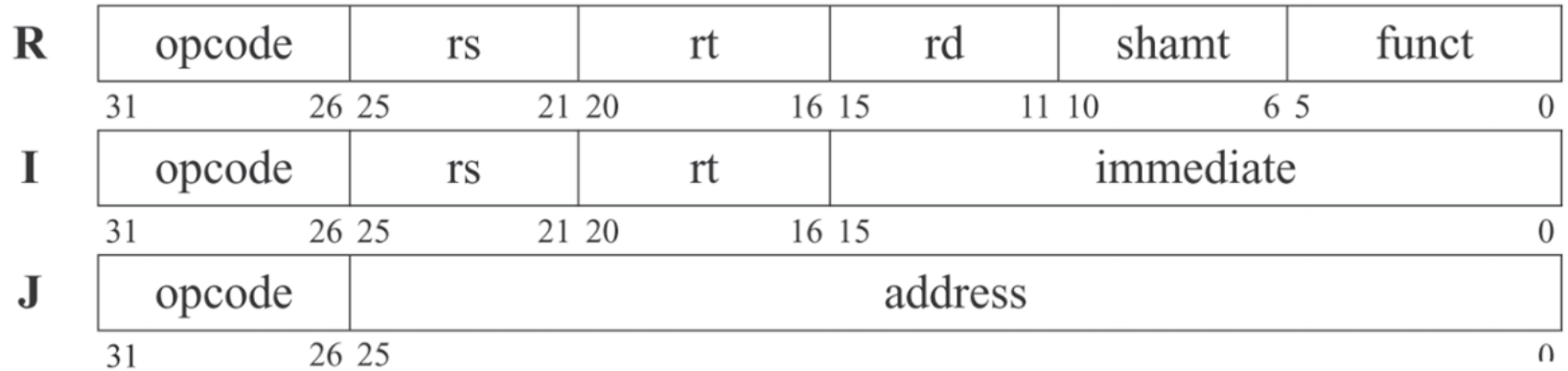

Assembly Language Characteristics

- One-to-one correspondence between machine instructions and assembly instructions
  - Programmer must think like the machine
- Inherently machine-dependent
- Converted to machine language by a program called an **assembler**

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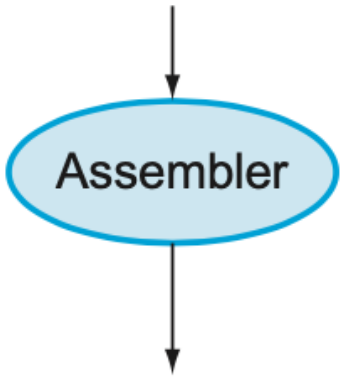

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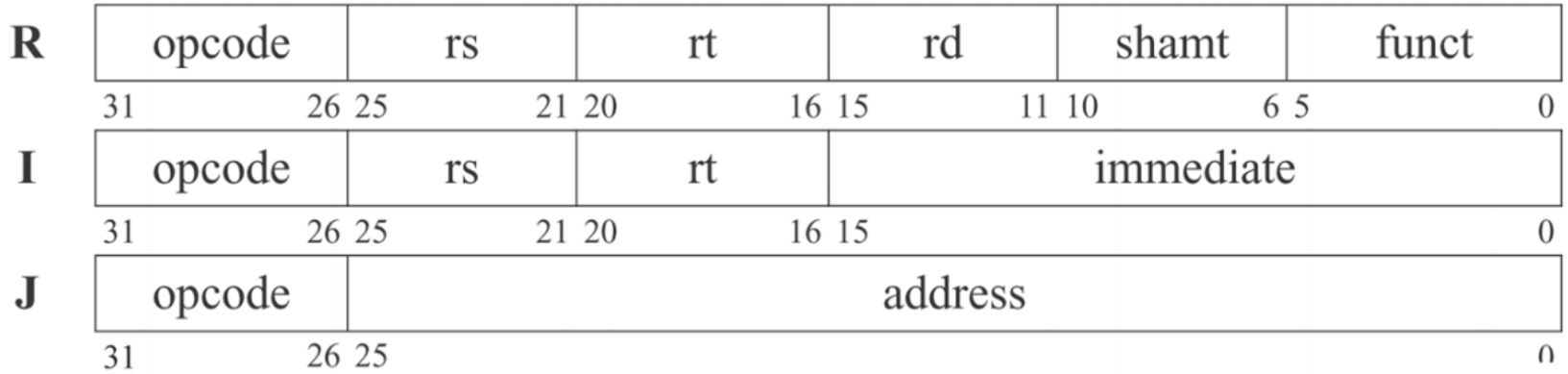

https://stackoverflow.com/questions/42392369/why-are-opcode-field-and-funct-field-apart-in-mips

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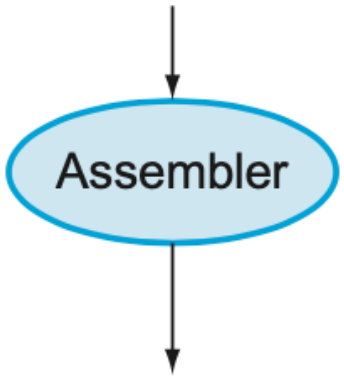

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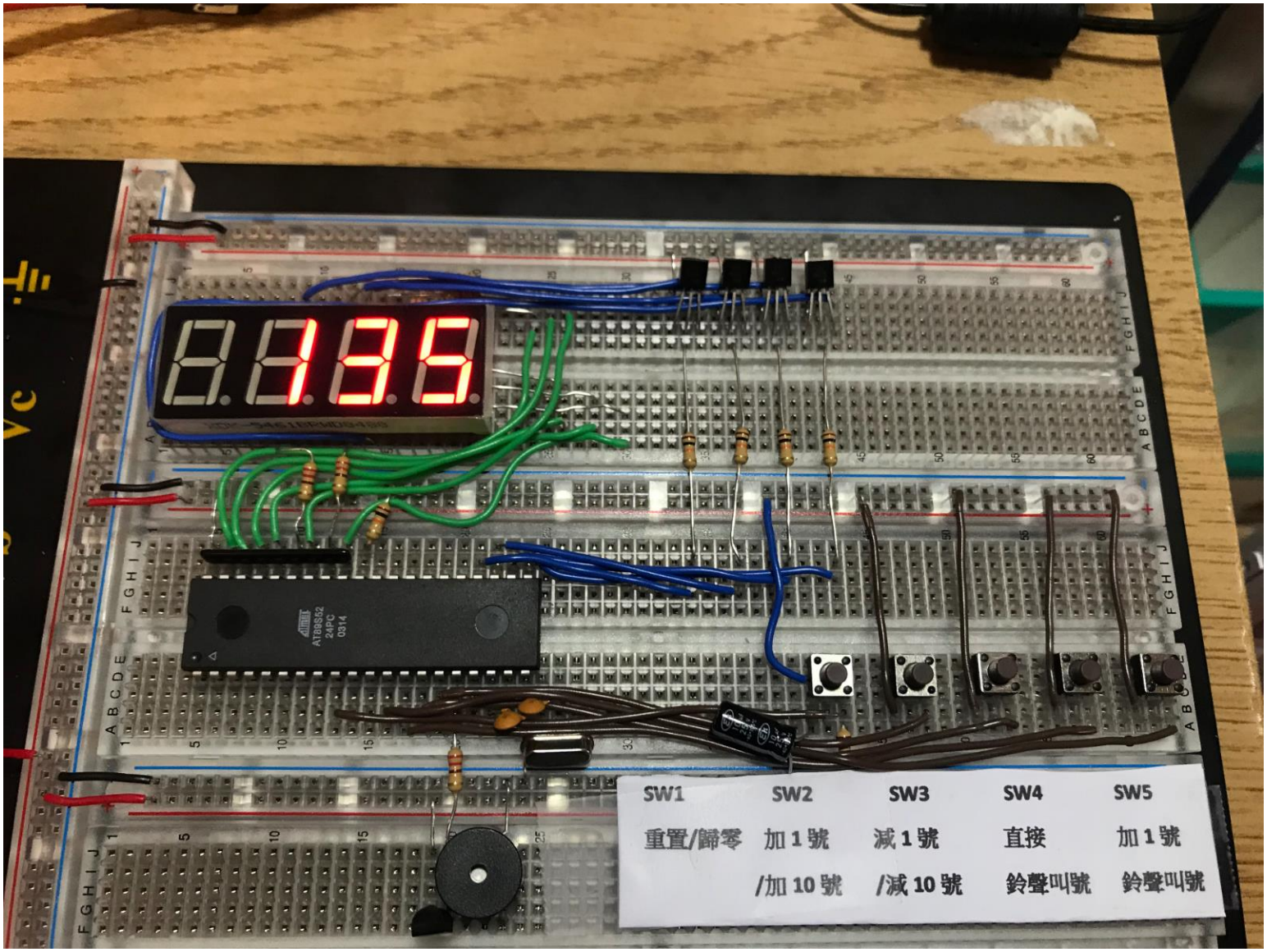

https://www.cakeresume.com/portfolios/8051?locale=zh-TW

Third Generation Language

- Uses high-level primitives
  - Similar to our pseudocode in Chapter 5
- Machine independent (mostly)
- Examples: FORTRAN, COBOL
- Each primitive corresponds to a sequence of machine language instructions
- Converted to machine language by a program called a **compiler**

Algorithm 1 Consensus-Based FA

procedure CFA($\mathcal{N}_{\bar{k}}, \epsilon_t, \alpha_{t,i}$)
  initialize $\mathbf{W}_{0,k} \leftarrow$ device k
  for each round $t = 1, 2, \ldots,$ **do** ▷ Main loop
    receive $\{\mathbf{W}_{t,i}\}_{i \in \mathcal{N}_{\bar{k}}}$ ▷ RX from neighbors
    $\boldsymbol{\psi}_{t,k} \leftarrow \mathbf{W}_{t,k}$
    for all devices $i \in \mathcal{N}_{\bar{k}}$ **do**
      $\boldsymbol{\psi}_{t,k} \leftarrow \boldsymbol{\psi}_{t,k} + \epsilon_t \alpha_{t,i} (\mathbf{W}_{t,i} - \mathbf{W}_{t,k})$
    end for
    $\mathbf{W}_{t+1,k} = \text{ModelUpdate}(\boldsymbol{\psi}_{t,k})$
    send$(\mathbf{W}_{t+1,k})$ ▷ TX to neighbors
  end for
end procedure
procedure MODELUPDATE($\boldsymbol{\psi}_{t,k}$) ▷ Local SGD
  $\mathcal{B} \leftarrow$ mini-batches of size B
  for batch $b \in \mathcal{B}$ **do** ▷ Local model update
    $\boldsymbol{\psi}_{t,k} \leftarrow \boldsymbol{\psi}_{t,k} - \mu_t \nabla L_{t,k}(\boldsymbol{\psi}_{t,k})$
  end for
  $\mathbf{W}_{t,k} \leftarrow \boldsymbol{\psi}_{t,k}$
  return$(\mathbf{W}_{t,k})$
end procedure

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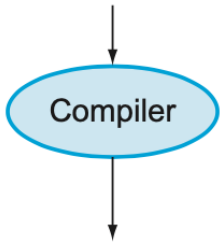

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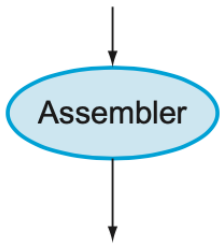

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Figure 6.1 Generations of programming languages

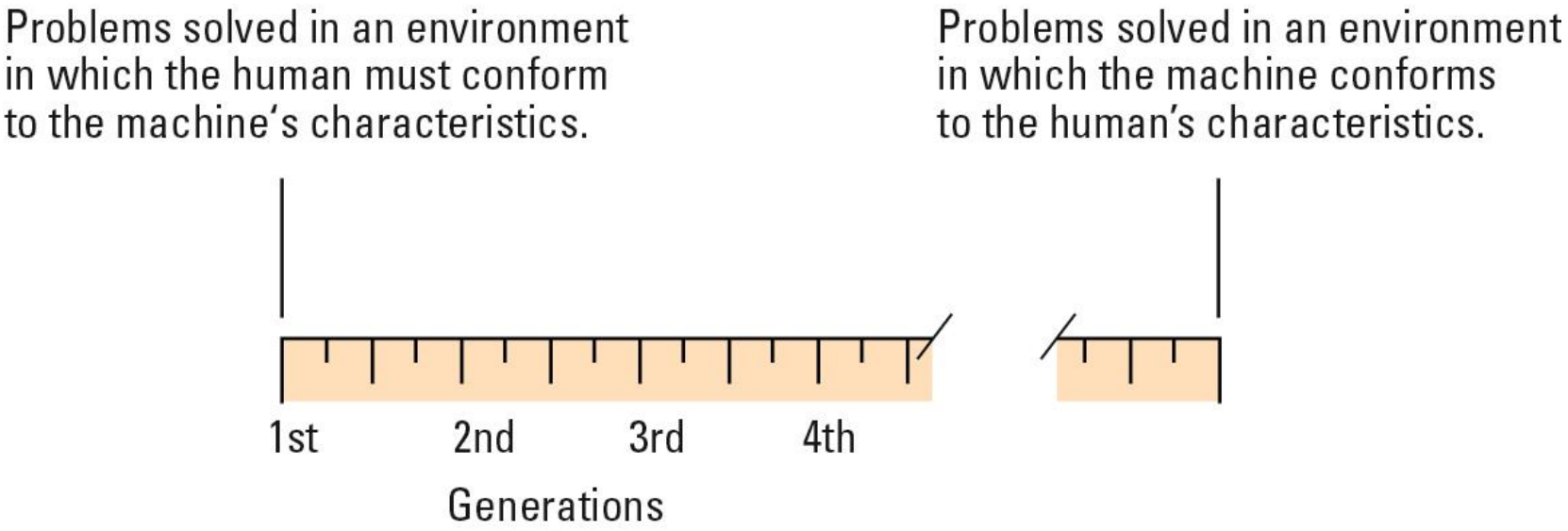
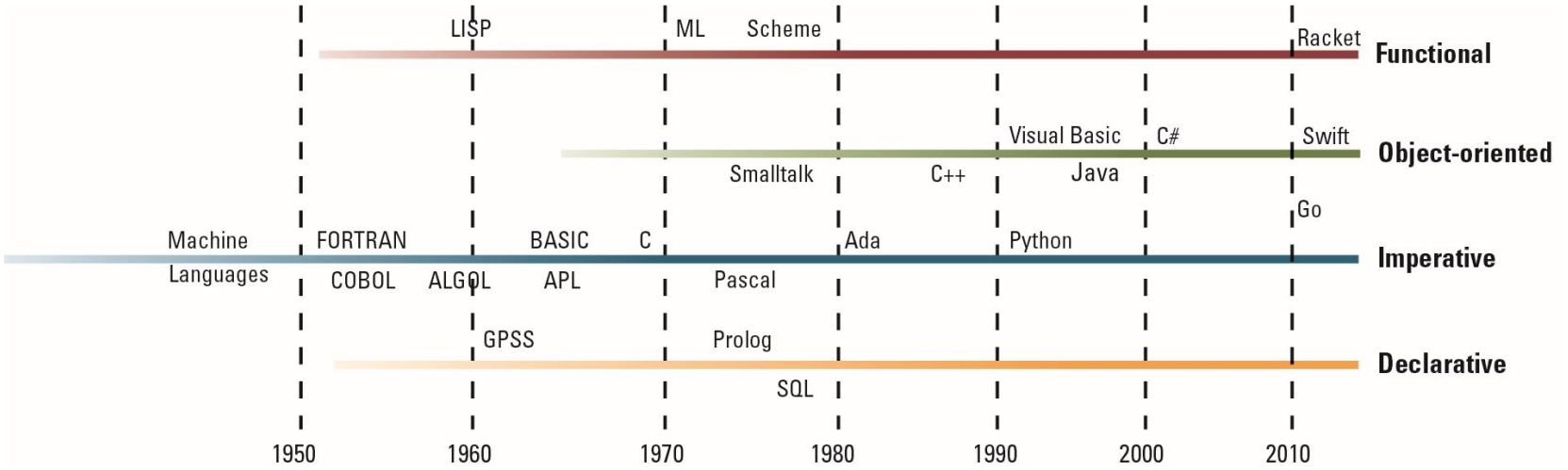


Figure 6.2 The evolution of programming paradigms



例子 [編輯]

彈簧 [編輯]

把質量為*M*的物體懸掛在勁度係數為*k*的彈簧的底端，則物體將進行簡諧運動，其方程式為：

$$\omega = 2\pi f = \sqrt{\frac{k}{M}}.$$

如果要計算它的週期，可以用以下的公式：

$$T = \frac{1}{f} = 2\pi\sqrt{\frac{M}{k}}\ .$$

https://zh.wikipedia.org/zh-tw/%E7%B0%A1%E8%AB%A7%E9%81%8B%E5%8B%95

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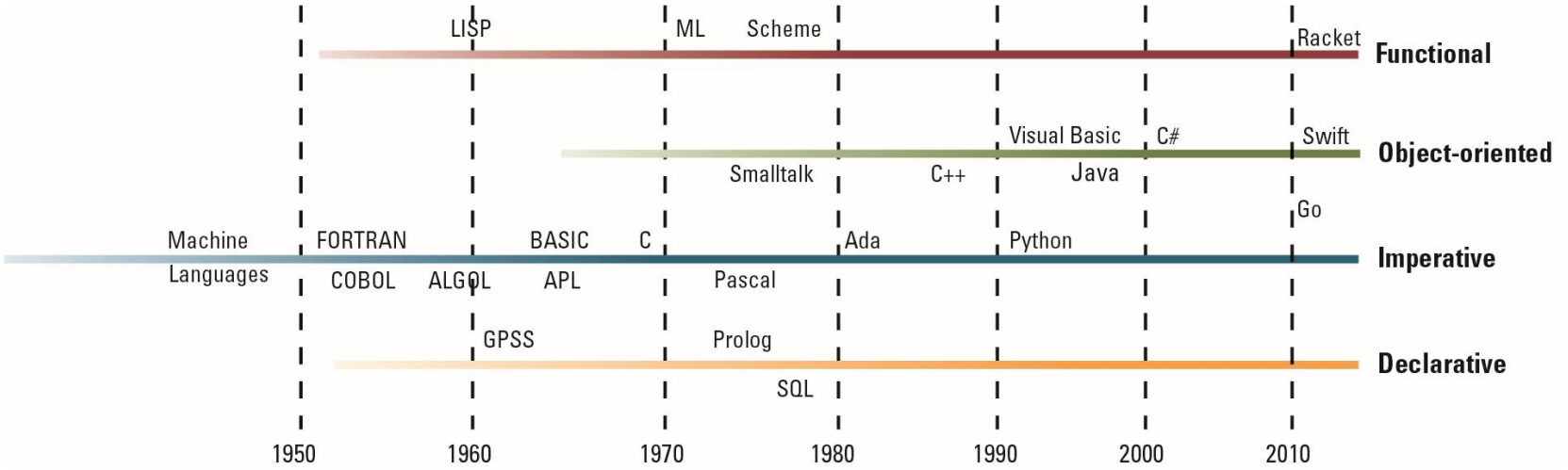

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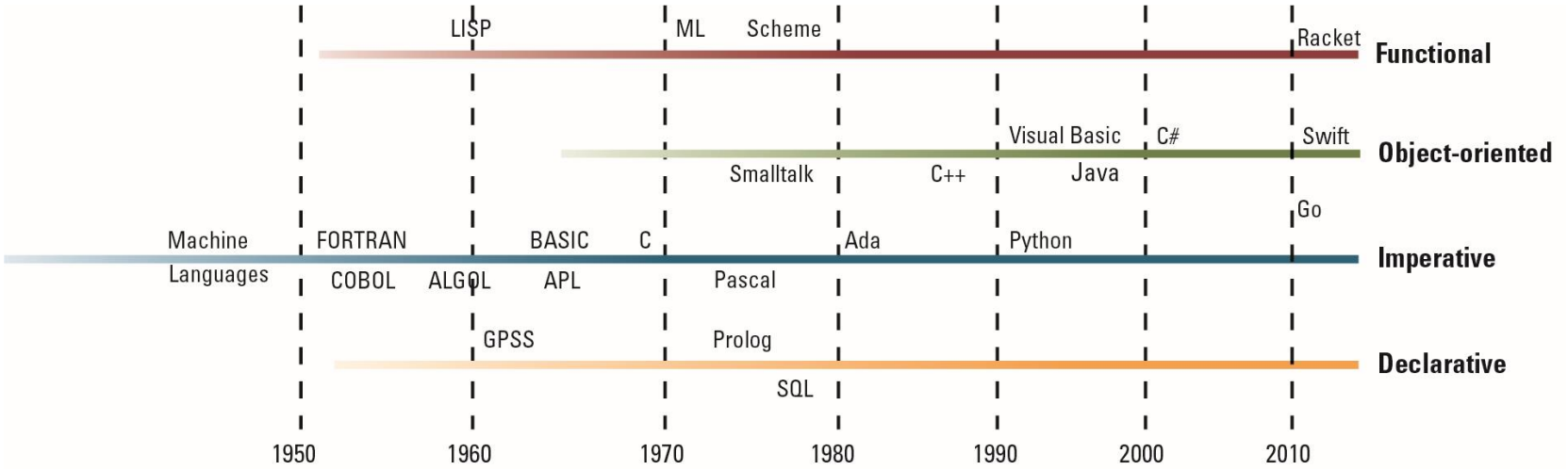


https://www.youtube.com/watch?v=pSoDUFdqVOU&t=479s
https://www.youtube.com/watch?v=3EkaxkNGXD8

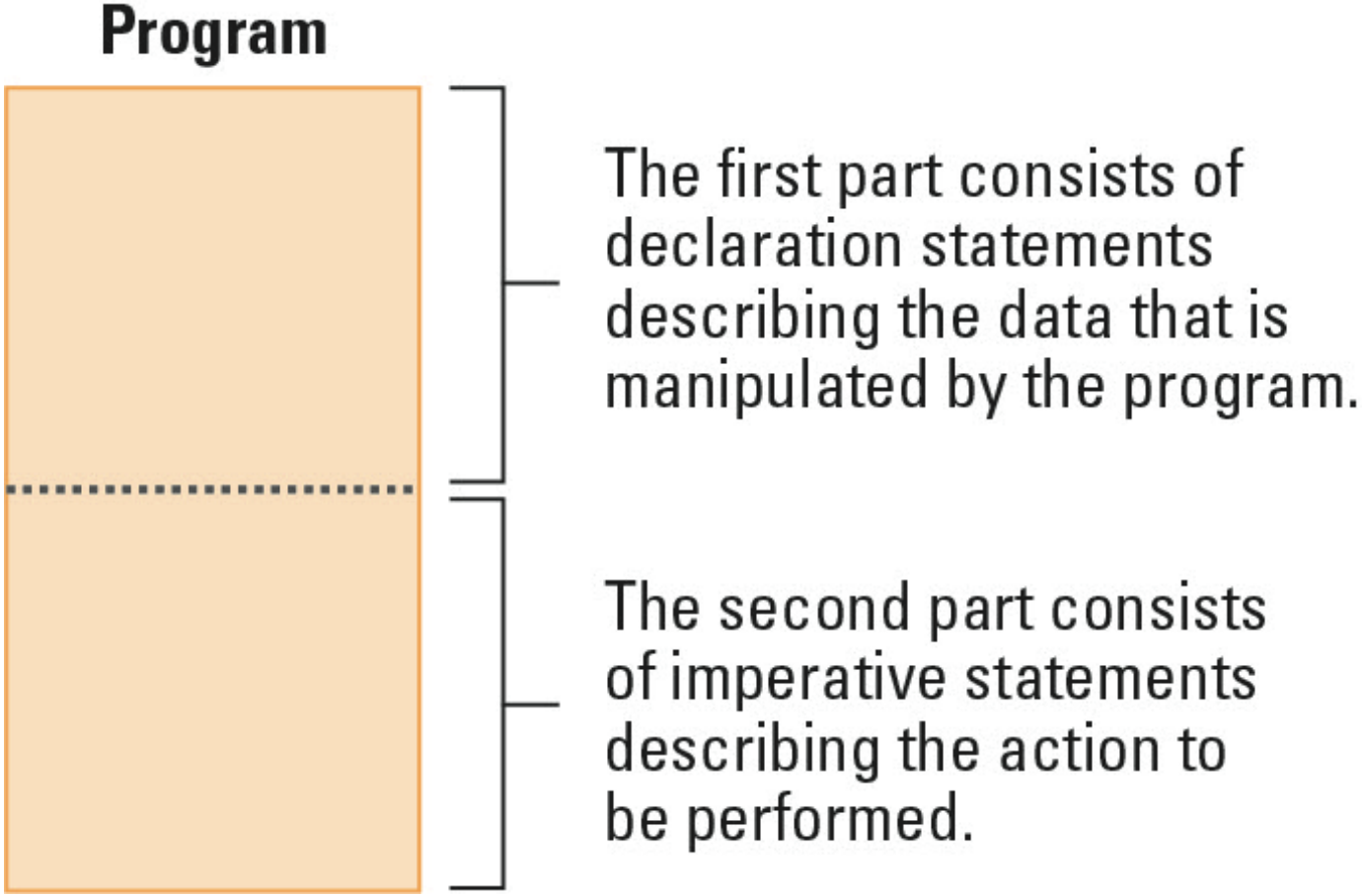
6.2 Traditional Programming Concepts

- Variables and Data Types
- Data Structure
- Constants and Literals
- Assignment Statements
- Control Statements
- Comments

6.2 Traditional Programming Concepts

- High-level languages (C, C++, Java, C#, FORTRAN) include many kinds of abstractions
  - Simple: constants, literals, variables
  - Complex: statements, expressions, control
  - Esoteric: procedures, modules, libraries

Figure 6.4 The composition of a typical imperative program or program unit



Process (其他版本 = jobs = task (Linux))

(一) Def:

A program in execution, 即執行中的程式

當 Process 被建立後, Process 的主要組成包含下列:

1. Code section (or Text section), 即 program code
2. Data section: containing the global variables
3. Stack: 包含 temporary data
   (e.g. Function parameters, Local variables, return address)
4. Heap: 包含 memory dynamically allocated during run time)
   (e.g. pointer 變數之要求空間)
5. Programming Counter and other register
   內放下一條指令之所在位址

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4. Heap: 包含 memory dynamically allocated during run time)
   (e.g. pointer 變數之要求空間)
5. Programming Counter and other register
   內放下一條指令之所在位址

(=) Process V.S. Program

Process	Program
A program in execution	Just a file stored in storage device
"Active" entity	"Passive" entity

圖示：

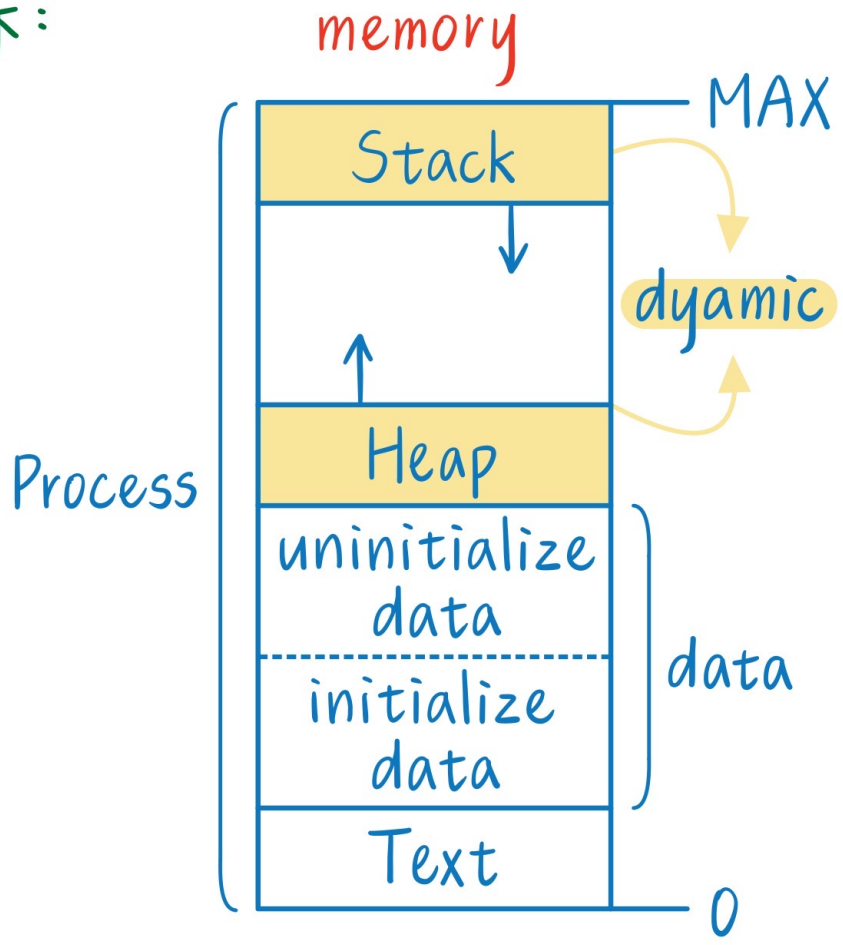
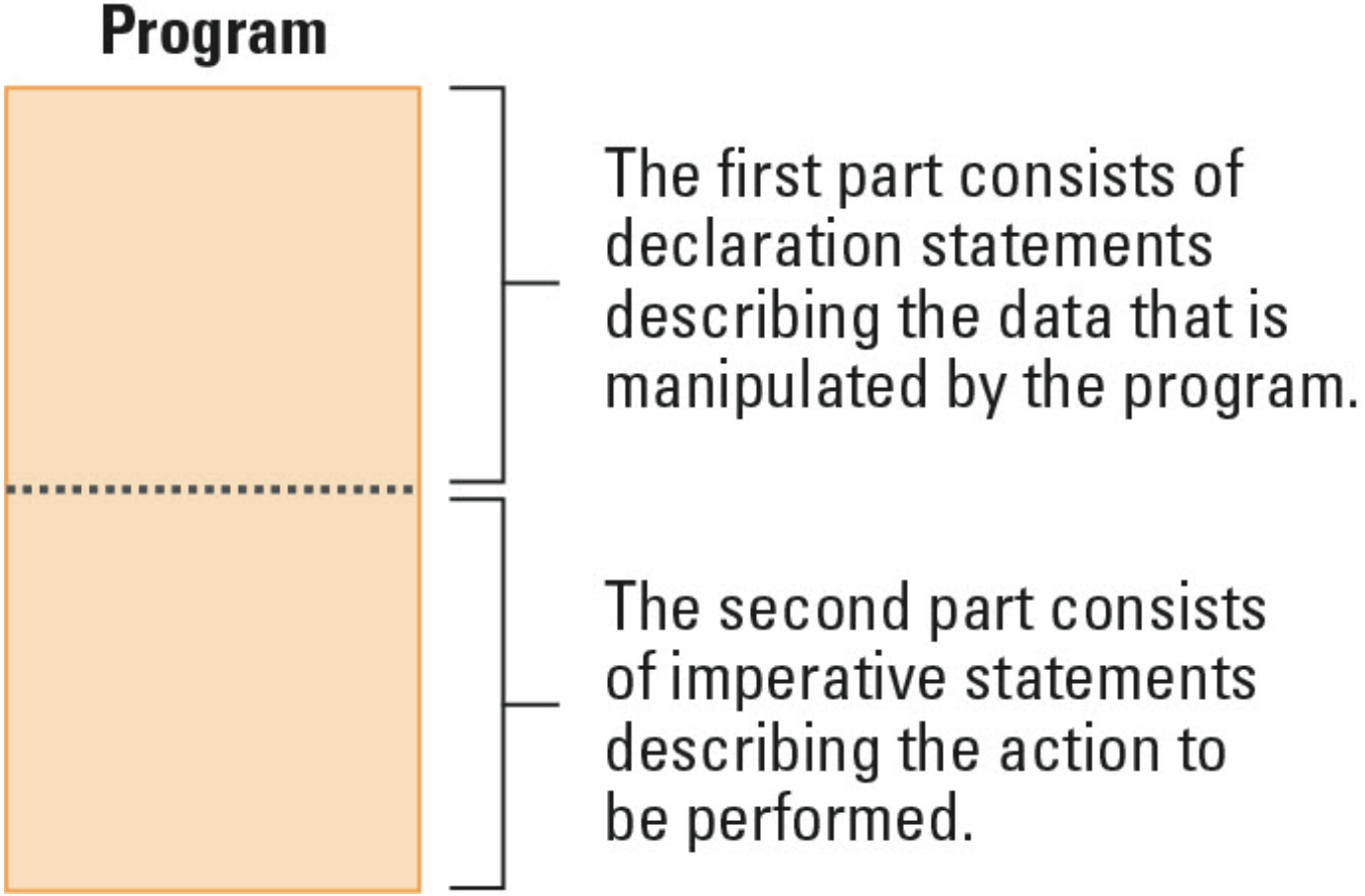

memory
MAX
Stack
dyamic
Heap
Process
uninitialize data
initialize data
data
Text
0

Figure 6.4 The composition of a typical imperative program or program unit



Data Types

- Integer: Whole numbers
- Real (float): Numbers with fractions
- Character: Symbols
- Boolean: True/false

Variables and Data types

```
float Length, Width;
int   Price, Total, Tax;
char  Symbol;

int   WeightLimit = 100;
```

6.2 Traditional Programming Concepts

- High-level languages (C, C++, Java, C#, FORTRAN) include many kinds of abstractions
  - Simple: constants, literals, variables
  - Complex: statements, expressions, control
  - Esoteric: procedures, modules, libraries

Variables and Data types

```
float Length, Width;
int   Price, Total, Tax;
char  Symbol;

int   WeightLimit = 100;
```

Data Structure

- Conceptual shape or arrangement of data
- A common data structure is the **array**
  - In C

```
int Scores[2][9];
```

  - In FORTRAN

```
INTEGER Scores(2,9)
```

Figure 6.5 A two-dimensional array with two rows and nine columns

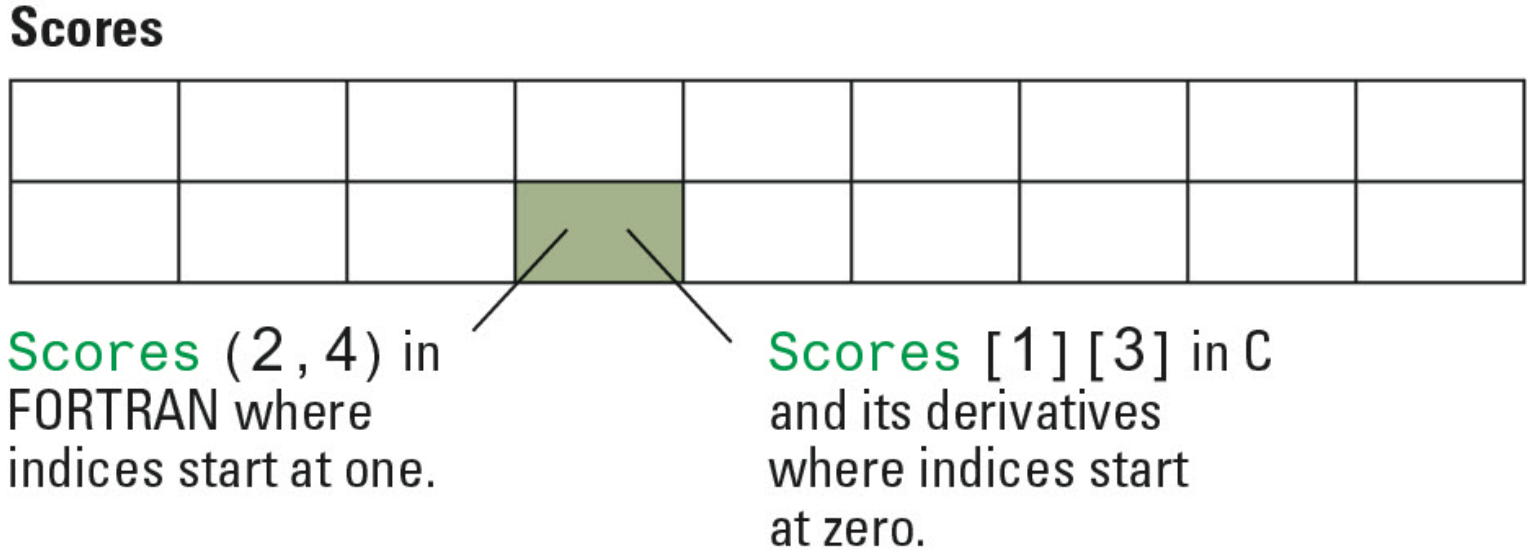
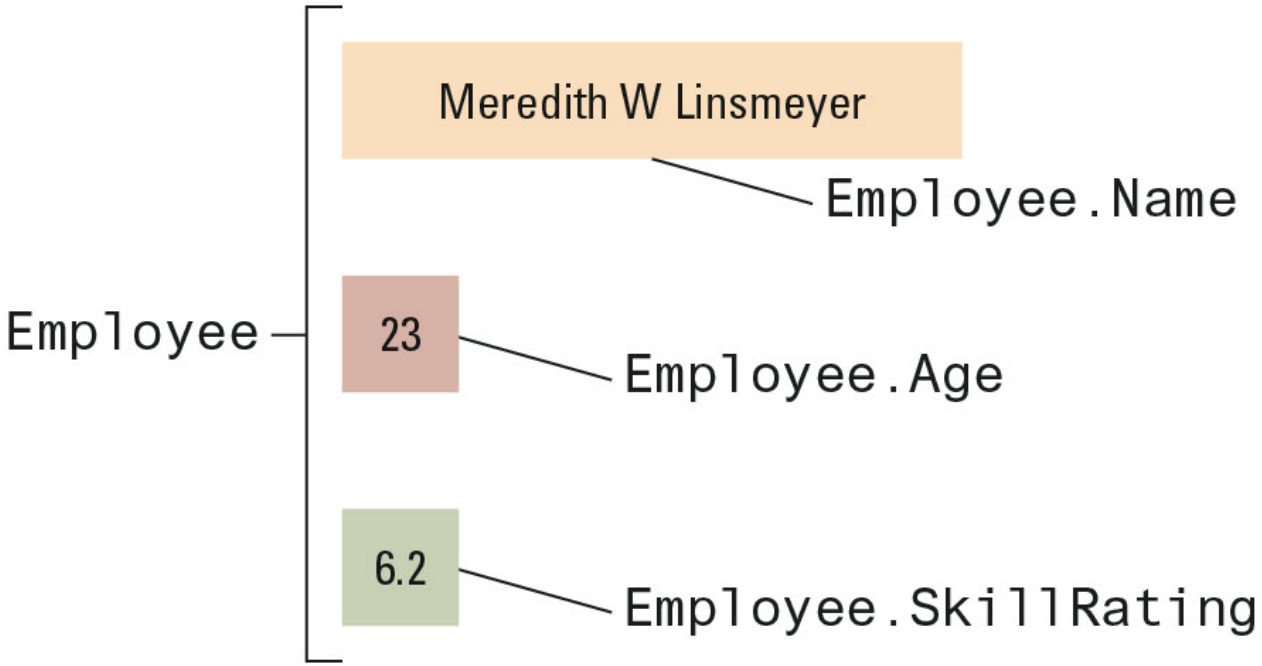


Figure 6.6 The conceptual structure of the aggregate type Employee




```
struct {    char  Name[25];
            int   Age;
            float SkillRating;
          } Employee;
```

Assignment Statements

- In C, C++, C#, Java

```
Z = X + y;
```

- In Ada

```
Z := X + y;
```

- In APL (A Programming Language)

```
Z ← X + y
```

Control Statements

- Go to statement

```
        goto 40
    20  Evade()
        goto 70
    40  if (KryptoniteLevel < LethalDose) then goto
60
        goto 20
    60  RescueDamsel()
    70  ...
```

- As a single statement

```
if (KryptoniteLevel < LethalDose):
    RescueDamsel()
else:
    Evade()
```

Control Statements (continued)

- If in Python

```
if (condition):
    statementA
else:
    statementB
```

- In C, C++, C#, and Java

```
if (condition) statementA; else statementB;
```

- In Ada

```
IF condition THEN
    statementA;
ELSE
    statementB;
END IF;
```

Control Statements (continued)

- While in Python

```
while (condition):
    body
```

- In C, C++, C#, and Java

```
while (condition)
{ body }
```

- In Ada

```
WHILE condition LOOP
    body
END LOOP;
```

Control Statements (continued)

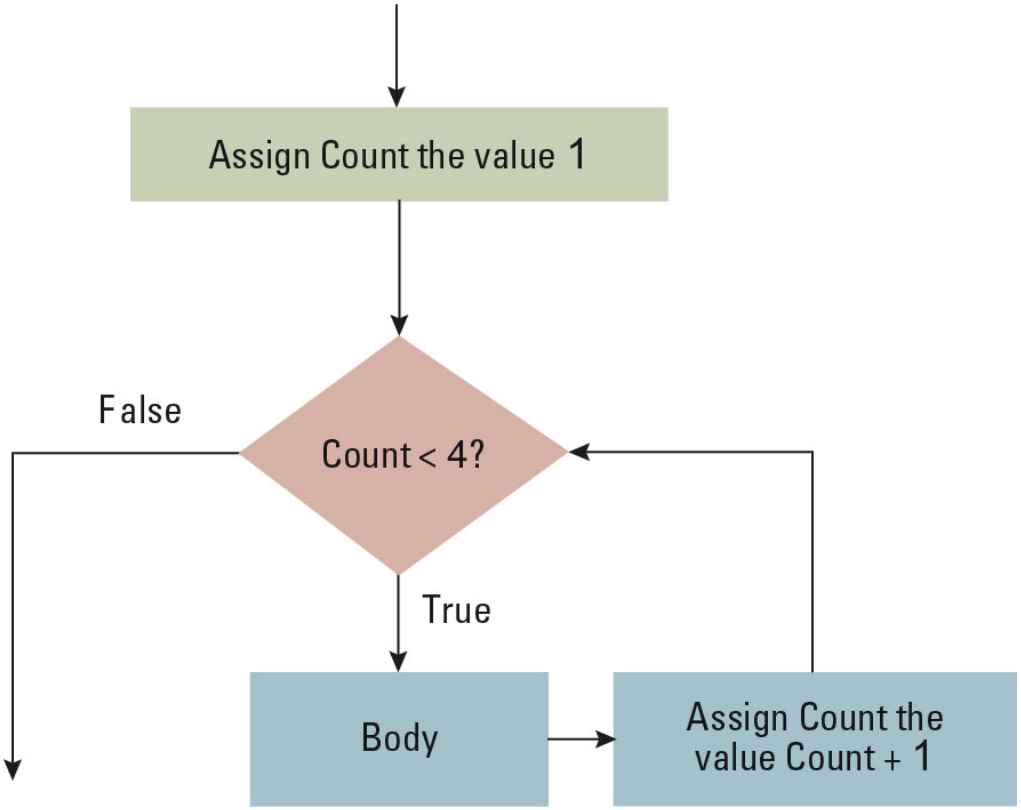
- Switch statement in C, C++, C#, and Java

```
switch (variable) {
    case 'A': statementA; break;
    case 'B': statementB; break;
    case 'C': statementC; break;
    default:  statementD; }
```

- In Ada

```
CASE variable IS
    WHEN 'A'=> statementA;
    WHEN 'B'=> statementB;
    WHEN 'C'=> statementC;
    WHEN OTHERS=> statementD;
END CASE;
```

Figure 6.7 The for loop structure and its representation in C++, C#, and Java




```
for (int Count = 1; Count < 4; Count++)
    body;
```

Comments

- Explanatory statements within a program
- Helpful when a human reads a program
- Ignored by the compiler

```
/* This is a comment in C/C++/Java. */

// This is a comment in C/C++/Java.
```

6.3 Procedural Units

- Many terms for this concept:
  - Subprogram, subroutine, procedure, method, function
- Unit begins with the function's **header**
- Local versus Global Variables
- Formal versus Actual Parameters
- Passing parameters by value versus reference

```
# A同學
v0_A = 10
a_A = 20
t_A = 200
s_A = v0_A * t_A + (0.5) * a_A * (t_A^2)

# B同學
v0_B = 5
a_B = 200
t_B = 100
s_B = v0_B * t_B + (0.5) * a_B * (t_B^2)

# C同學
v0_C = 50
a_C = 20
t_C = 1
s_C = v0_C * t_C + (0.5) * a_C * (t_C^2)
```

```python
# 距離公式
def vt_func(v0, a, t):
    s = v0 * t + (0.5) * a * (t^2)
    return s

# A同學
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a_B = 200
t_B = 100
s_A = vt_func(v0_B, a_B, t_B)

# C同學
v0_C = 50
a_C = 20
t_C = 1
s_A = vt_func(v0_C, a_C, t_C)
```

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# A同學
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s_A = vt_func(v0_A, a_A, t_A)

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v0_B = 5
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t_B = 100
s_A = vt_func(v0_B, a_B, t_B)

# C同學
v0_C = 50
a_C = 20
t_C = 1
s_A = vt_func(v0_C, a_C, t_C)
```

6.3 Procedural Units

- Many terms for this concept:
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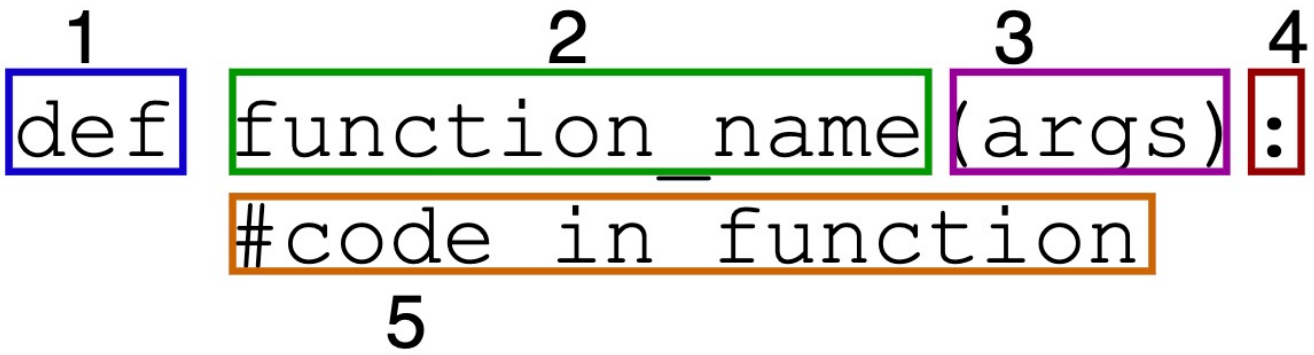
- Passing parameters by value versus reference

Creating a Function

To create a function, you would have to first write a function header. A function header looks like this:

```
def function_name(args):
    #code in function
```

Let's break it down:



1. The `def` keyword just indicates that we are starting to write a function header
2. The name of the function goes here. You can name a function in the same ways you can name a variable.
3. Arguments go here. This is covered in the next lesson, so here you would usually leave it as blank parentheses `()`
4. Colon is required! Don't forget!
5. The code underneath that is tabbed is the code inside the function.

https://teachen.info/cspp/unit4/u0401-functions.html

6.3 Procedural Units

- Many terms for this concept:
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    s = v0 * t + (0.5) * a * (t^2)
    return s

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t_B = 100
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s_A = vt_func(v0_C, a_C, t_C)
```

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Figure 6.8 The flow of control involving a function

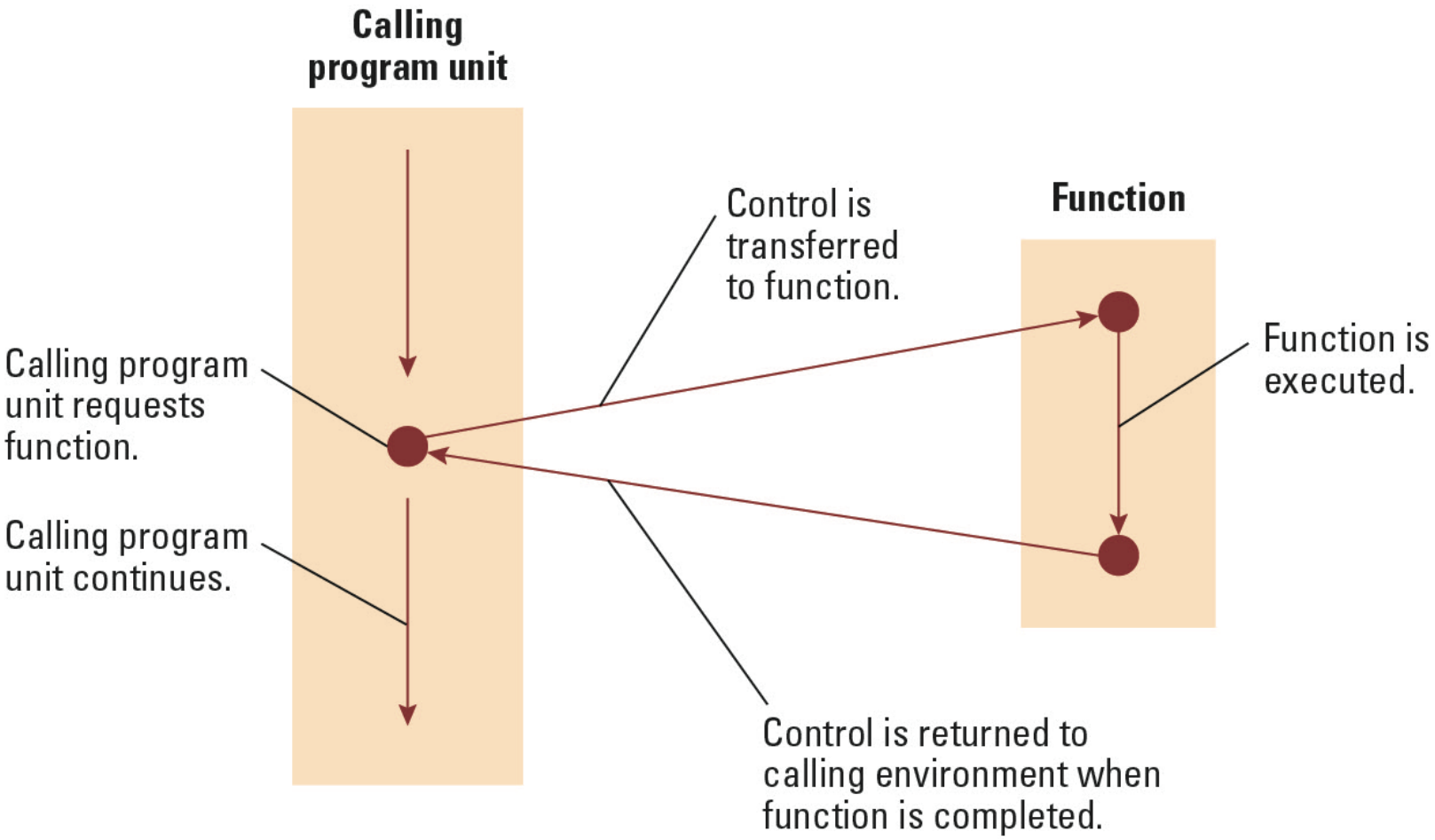


Figure 6.9 The function ProjectPopulation written in the programming language C

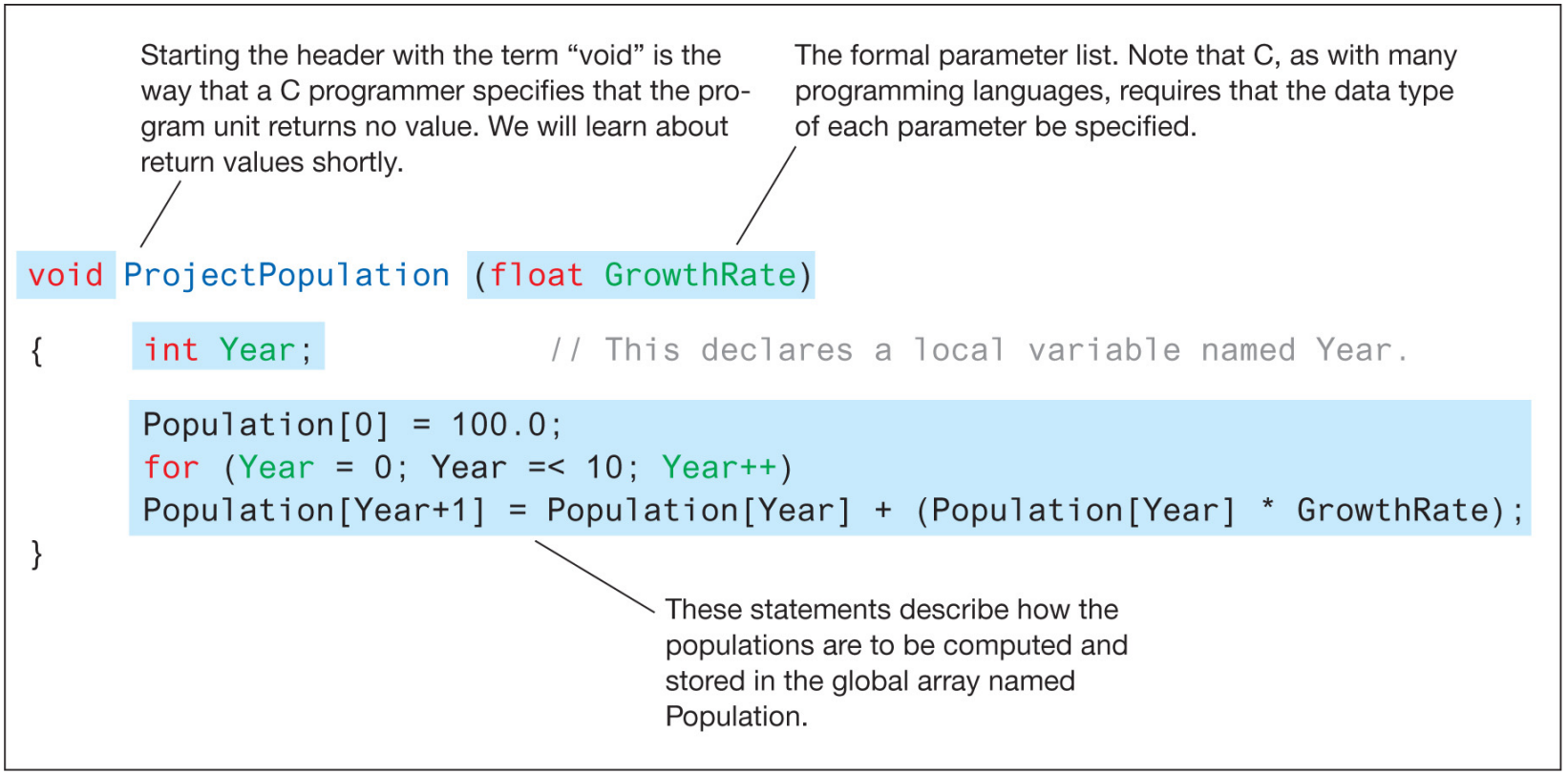


Figure 6.12 The fruitful function CylinderVolume written in the programming language C

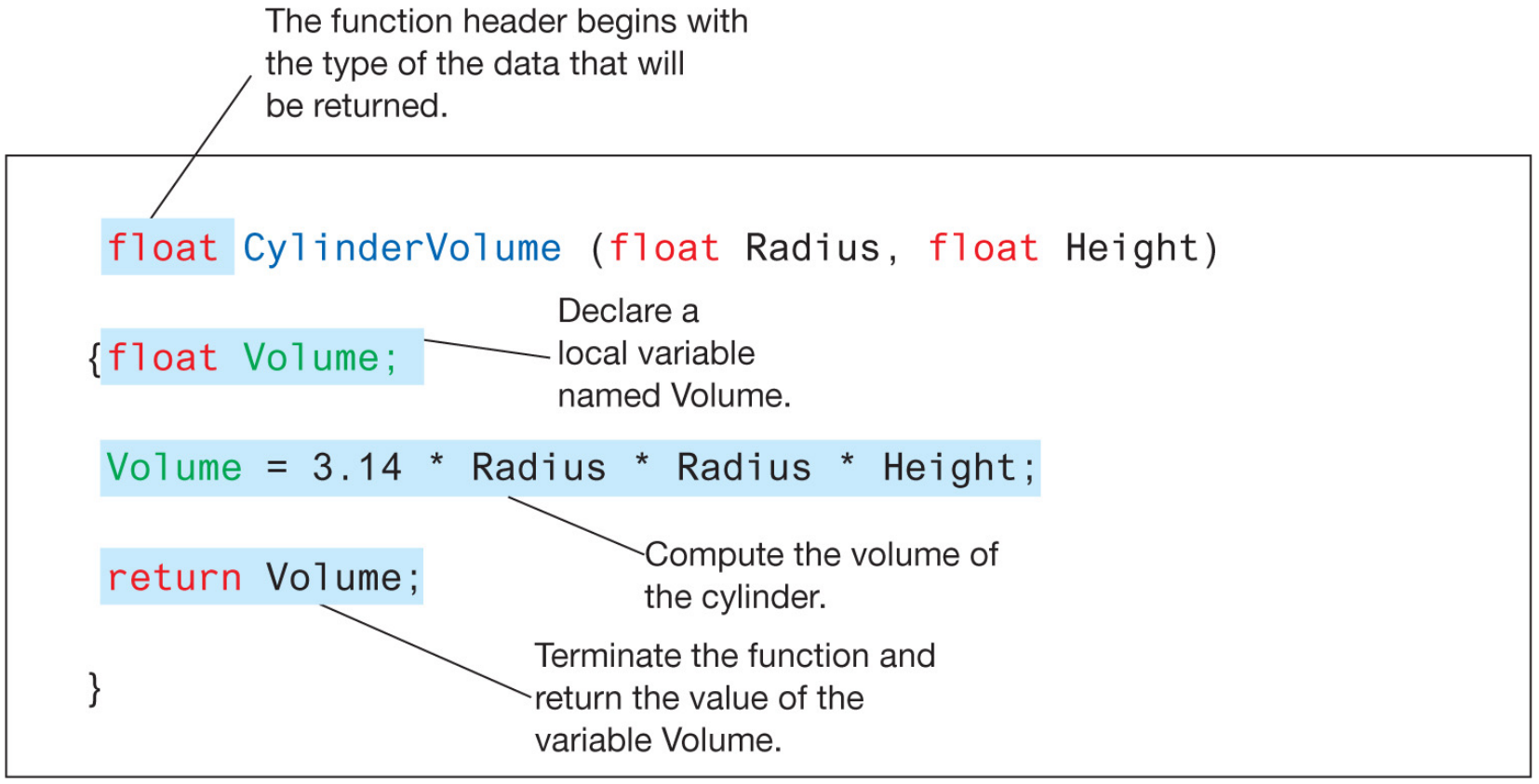
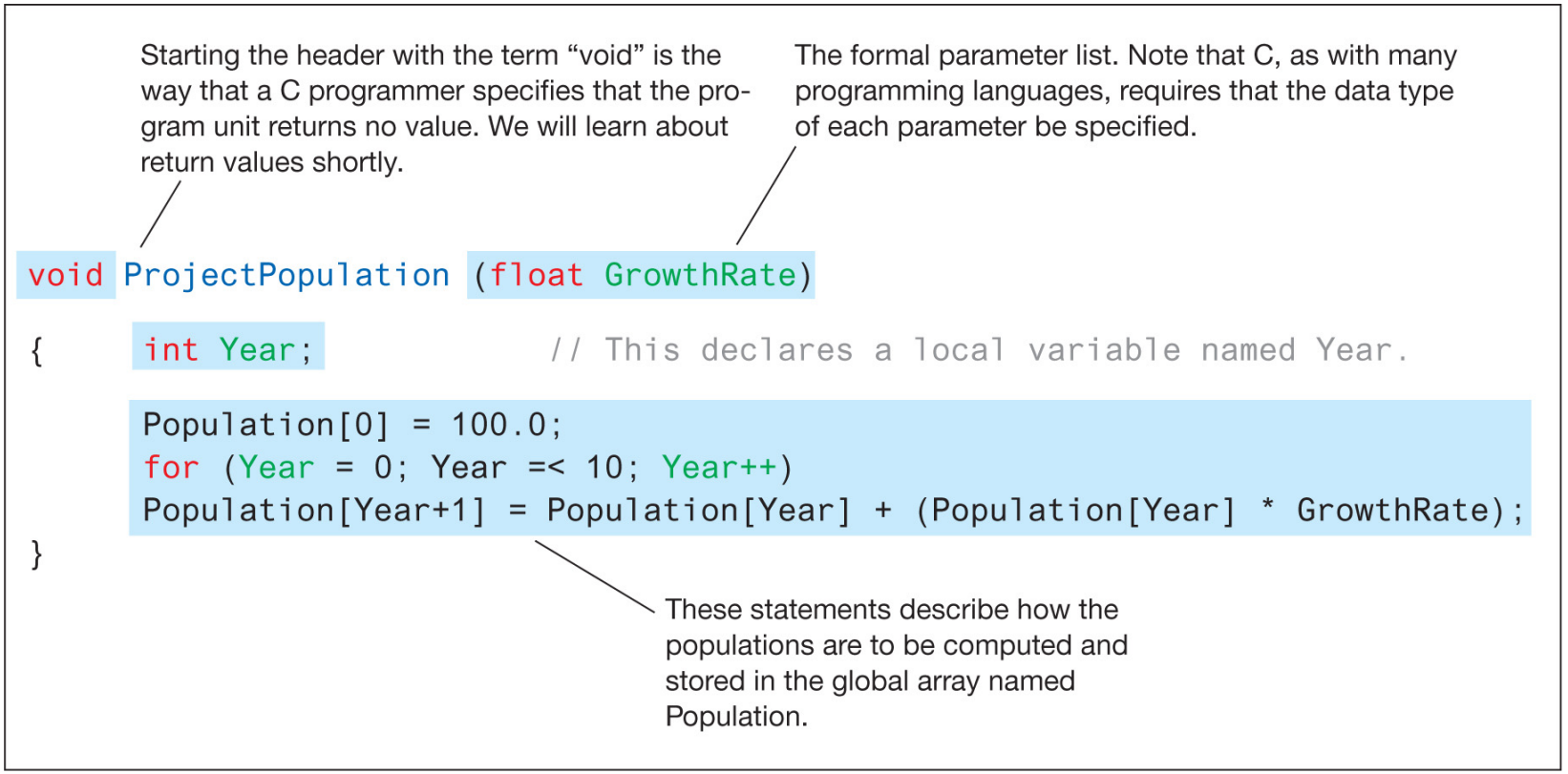


Figure 6.9 The function ProjectPopulation written in the programming language C



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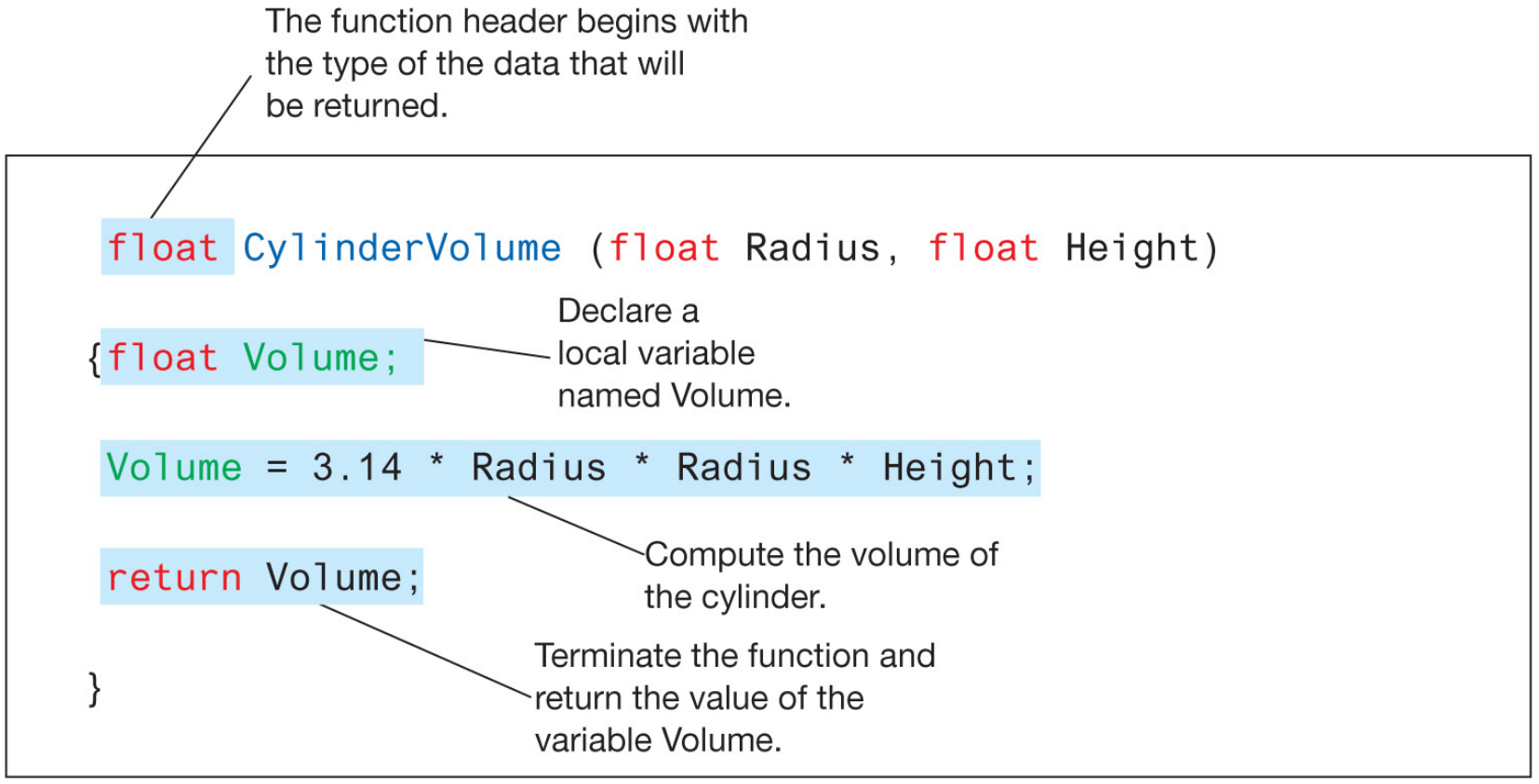

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t_C = 1
s_A = vt_func(v0_C, a_C, t_C)
```

6.3 Procedural Units

- Many terms for this concept:
  - Subprogram, subroutine, procedure, method, function
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- Local versus Global Variables
- Formal versus Actual Parameters
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Figure 6.10 Executing the function Demo and passing parameters by value

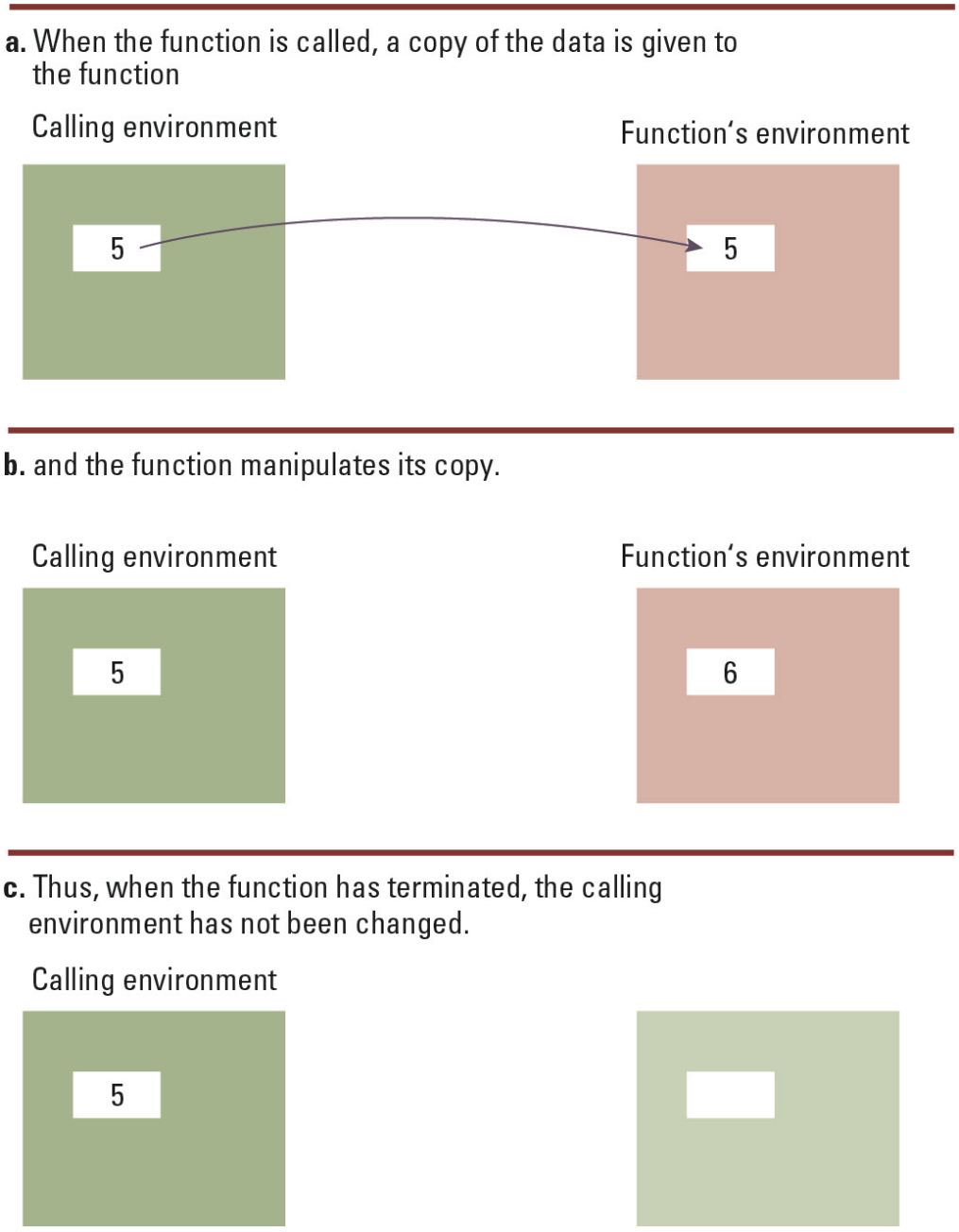
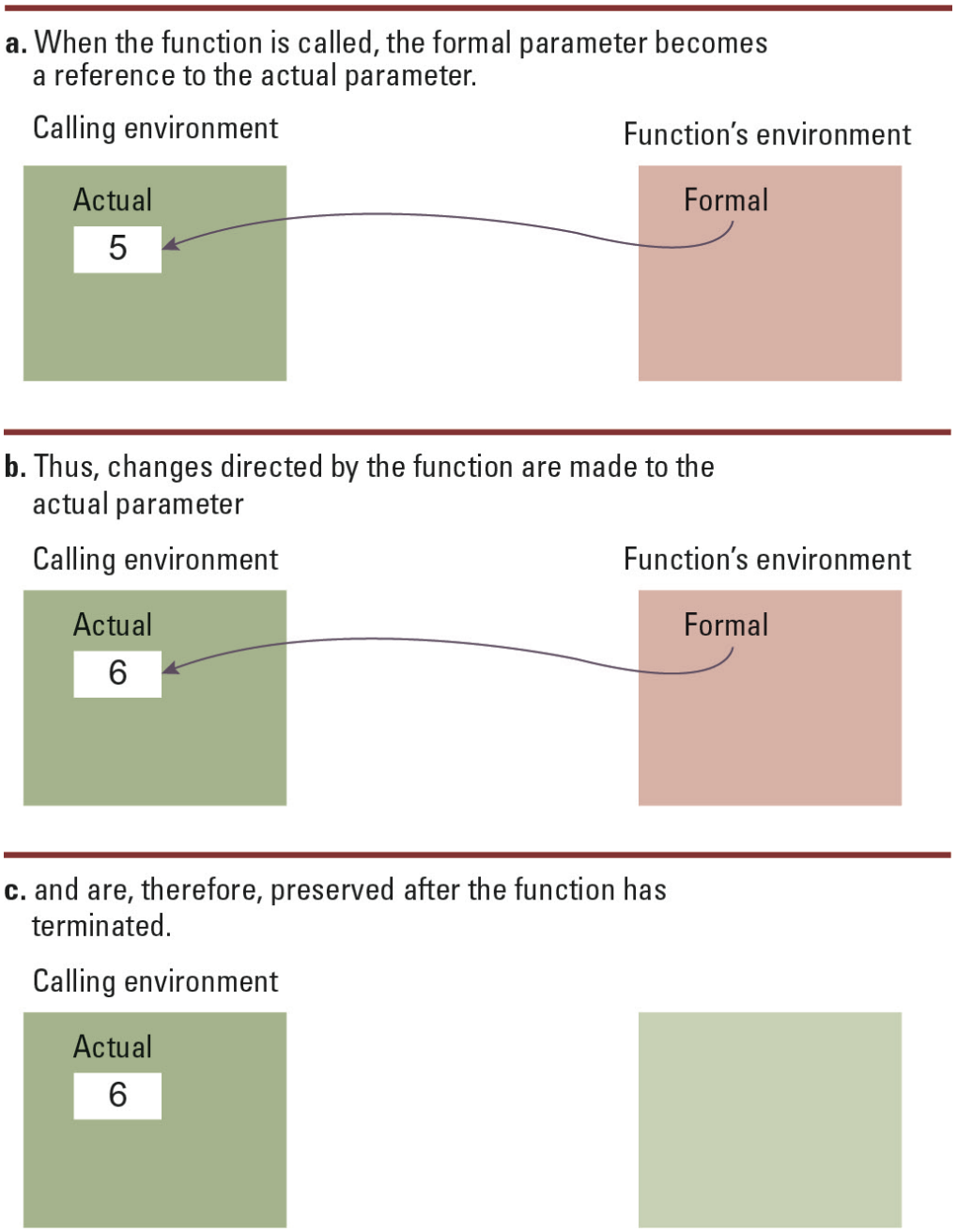


Figure 6.11 Executing the function Demo and passing parameters by reference



6.4 Language Implementation

- The process of converting a program written in a high-level language into a machine-executable form.
  - The Lexical Analyzer recognizes which strings of symbols represent a single entity, or token.
  - The Parser groups tokens into statements, using syntax diagrams to make parse trees.
  - The Code Generator constructs machine-language instructions to implement the statements.

Figure 6.13 The translation process

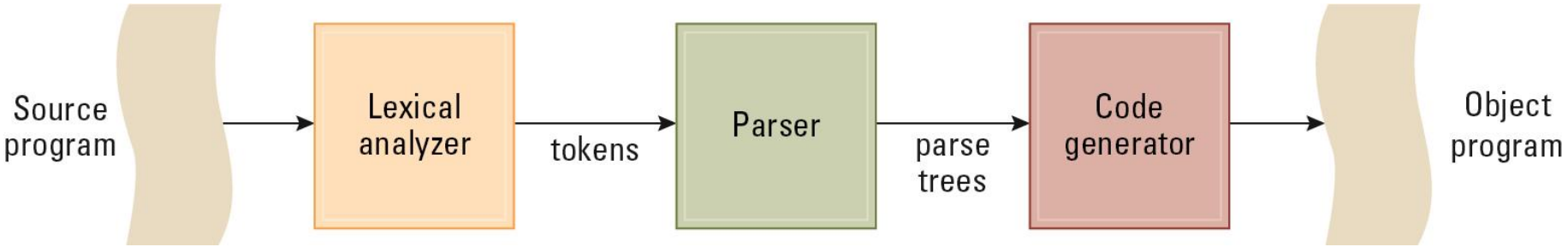


Figure 6.14 A syntax diagram of Python's if-then-else statement

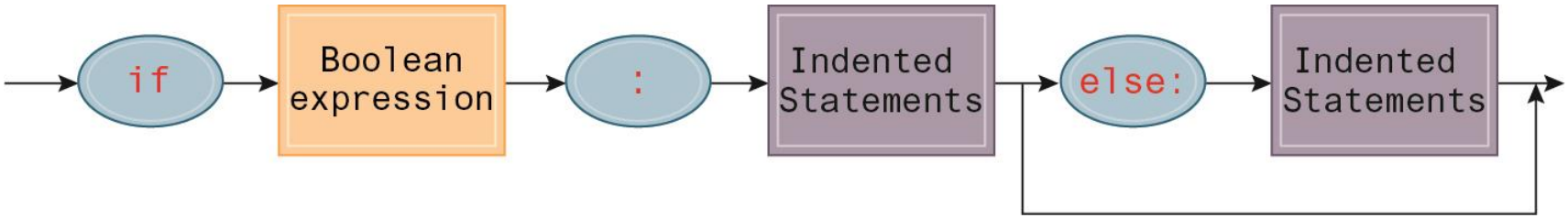


Figure 6.15 Syntax diagrams describing the structure of a simple algebraic expression

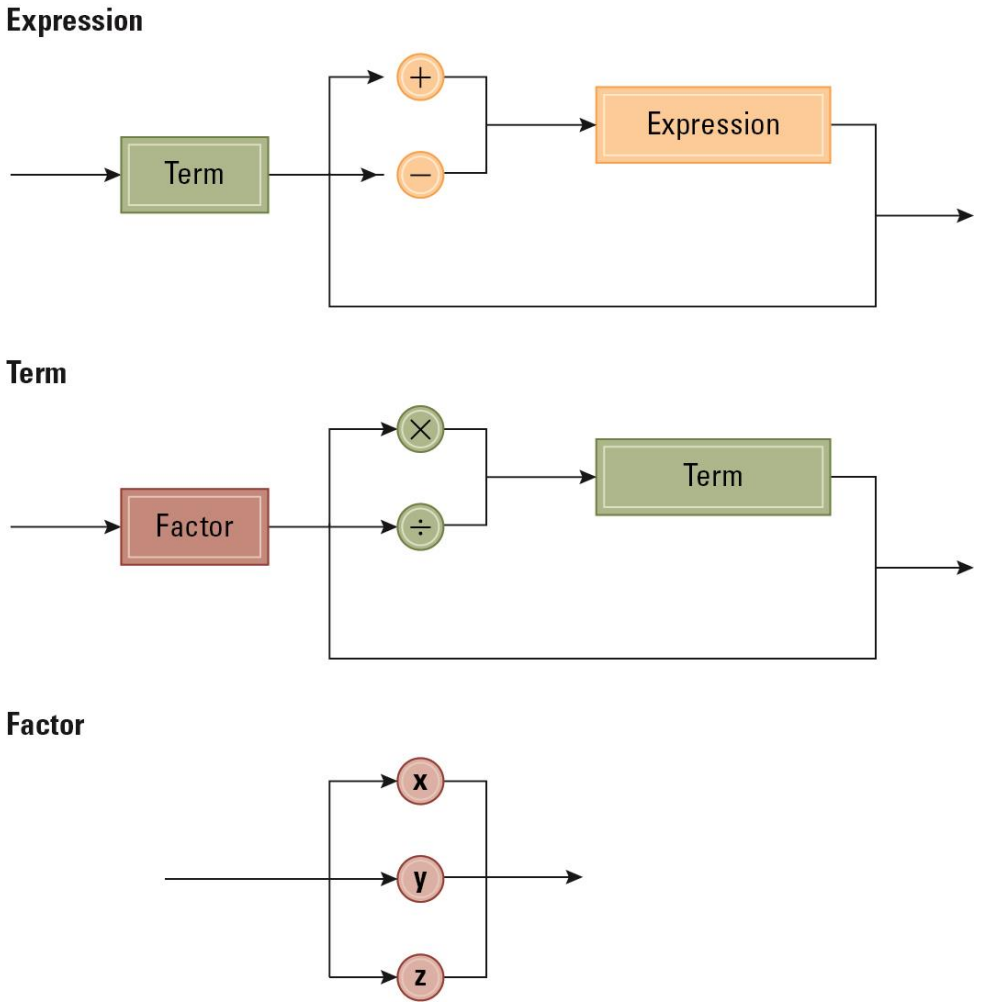


Figure 6.16 The parse tree for the string x + y * z based on the syntax diagrams in Figure 6.17

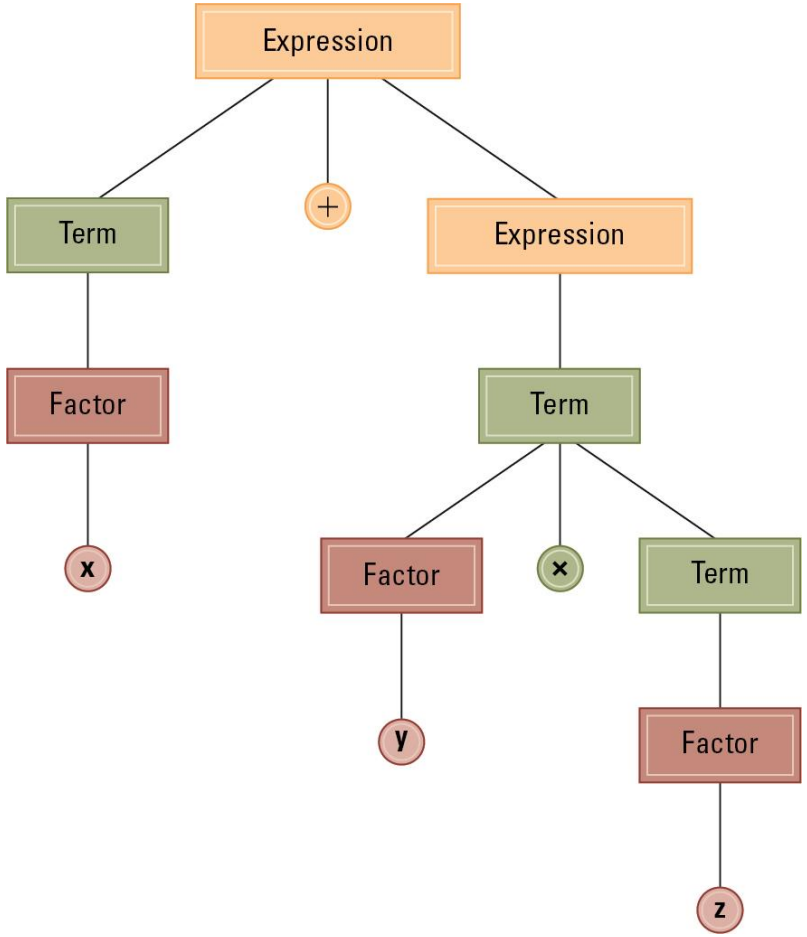
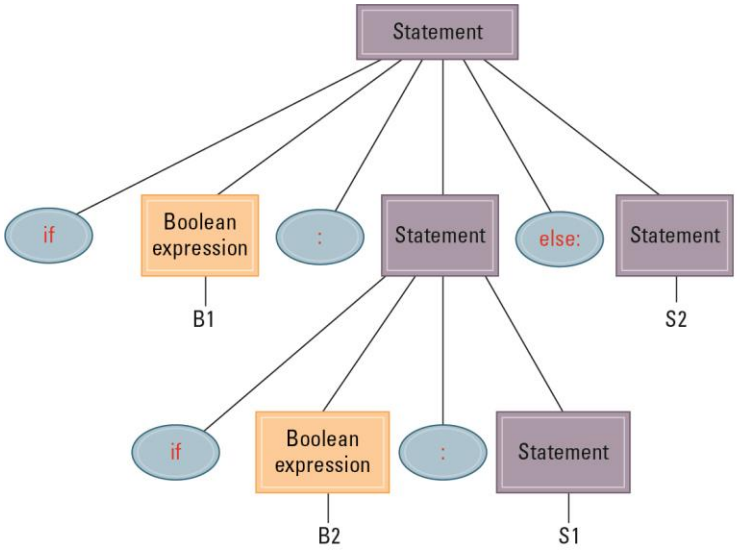


Figure 6.17 Two distinct parse trees for the statement if B1 then if B2 then S1 else S2



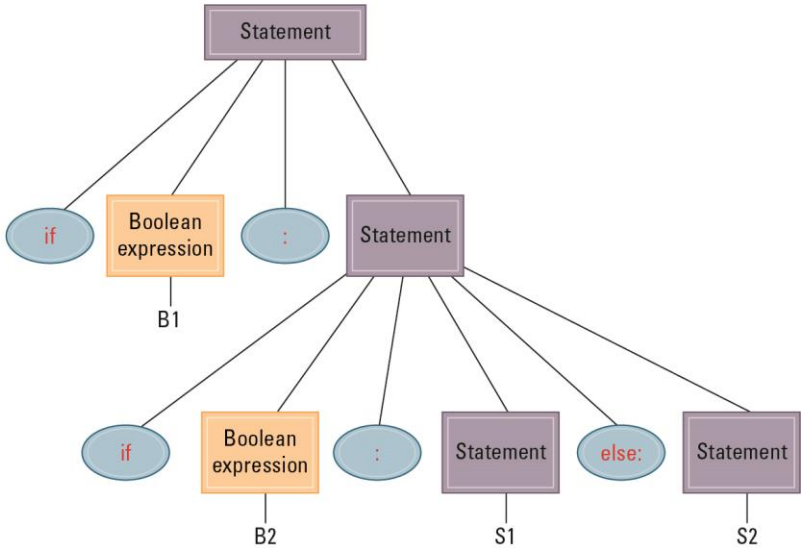
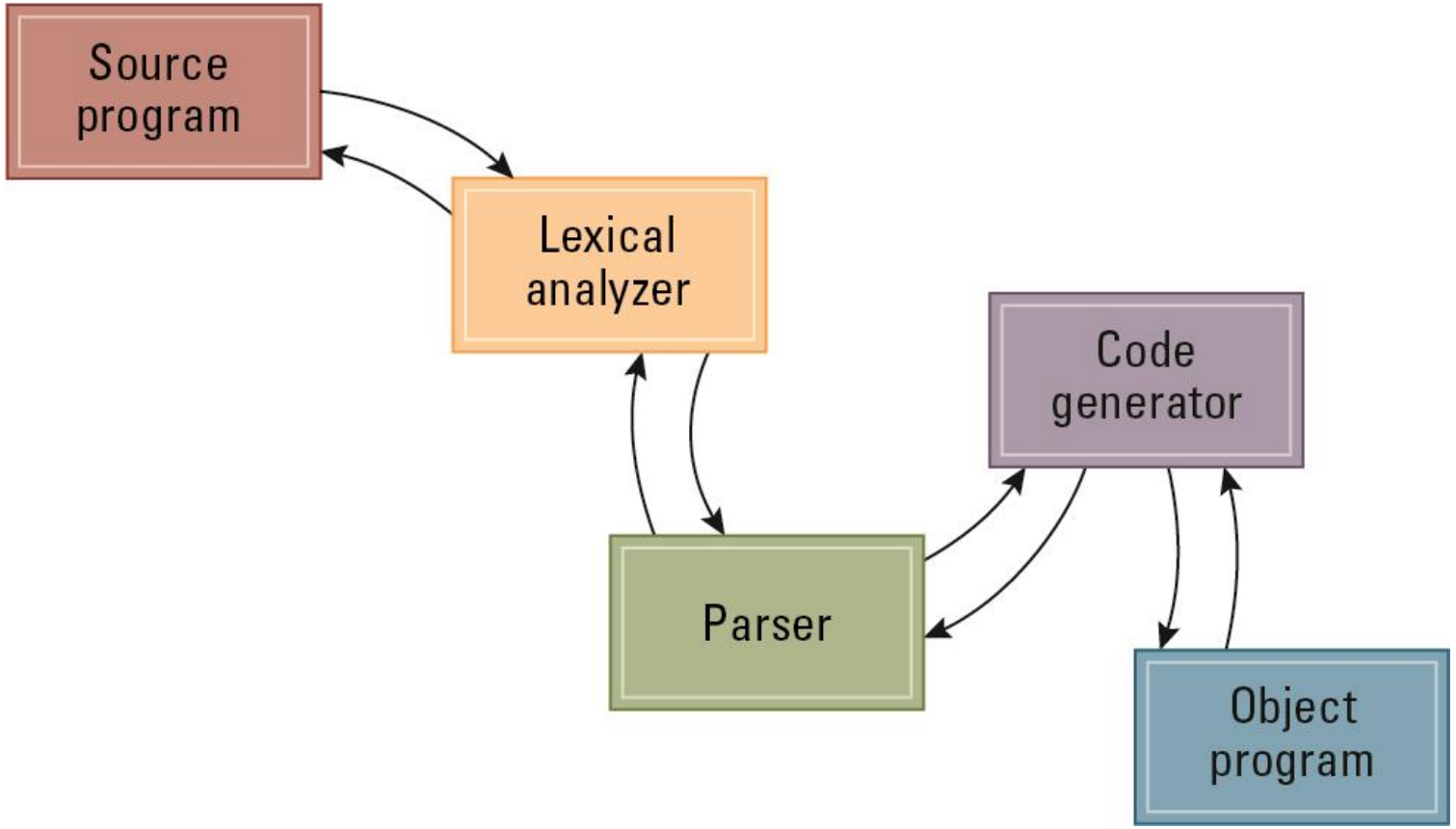


Figure 6.18 An object-oriented approach to the translation process

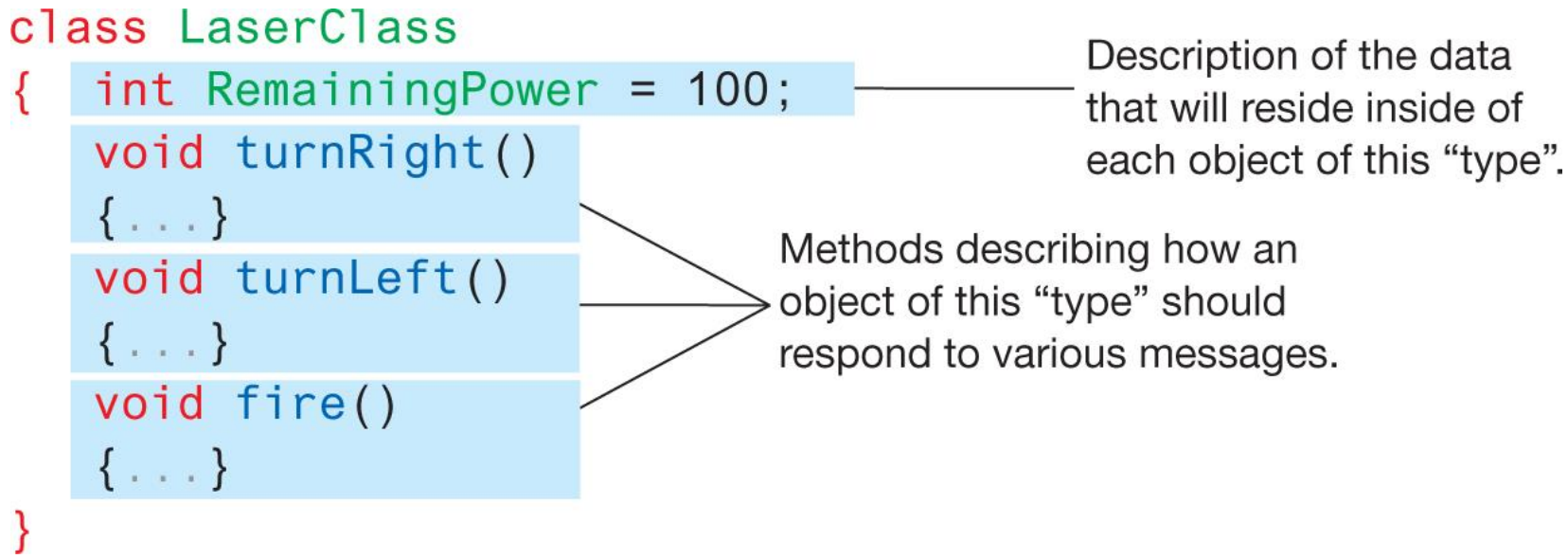


6.5 Object-Oriented Programming

- **Object:** Active program unit containing both data and procedures
- **Class:** A template from which objects are constructed

An object is called an **instance** of the class.

Figure 6.19 The structure of a class describing a laser weapon in a computer game



Components of an Object

- **Instance Variable:** Variable within an object
  - Holds information within the object
- **Method:** Procedure within an object
  - Describes the actions that the object can perform
- **Constructor:** Special method used to initialize a new object when it is first constructed

Figure 6.21 A class with a constructor

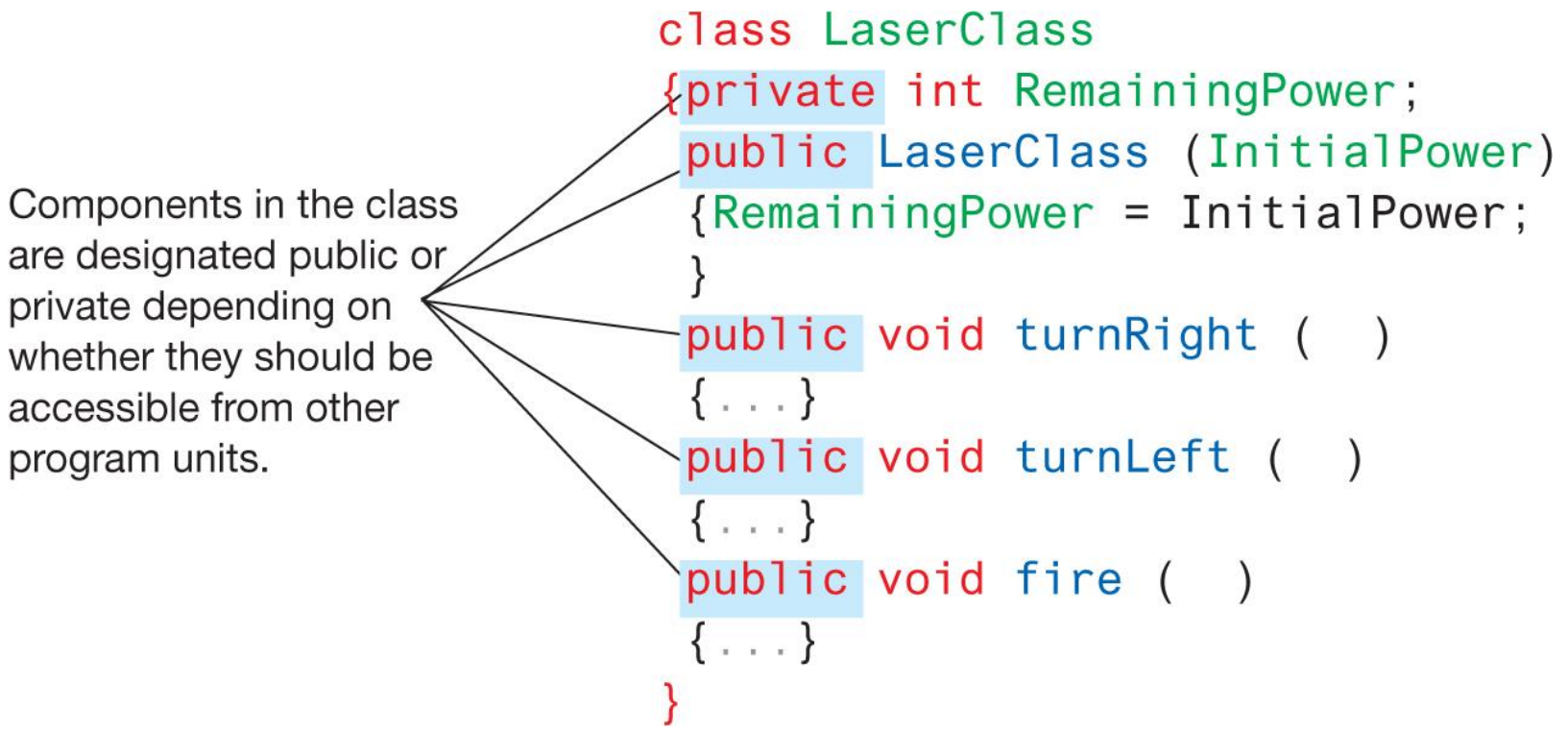
```
class LaserClass
{ int RemainingPower;
  LaserClass(InitialPower)
  { RemainingPower = InitialPower;
  }
  void turnRight()
  {...}
  void turnLeft()
  {...}
  void fire()
  {...}
}
```

Constructor assigns a value to RemainingPower when an object is created.

Object Integrity

- **Encapsulation:** A way of restricting access to the internal components of an object
  - Private
  - Public

Figure 6.22 Our LaserClass definition using encapsulation as it would appear in a Java or C# program



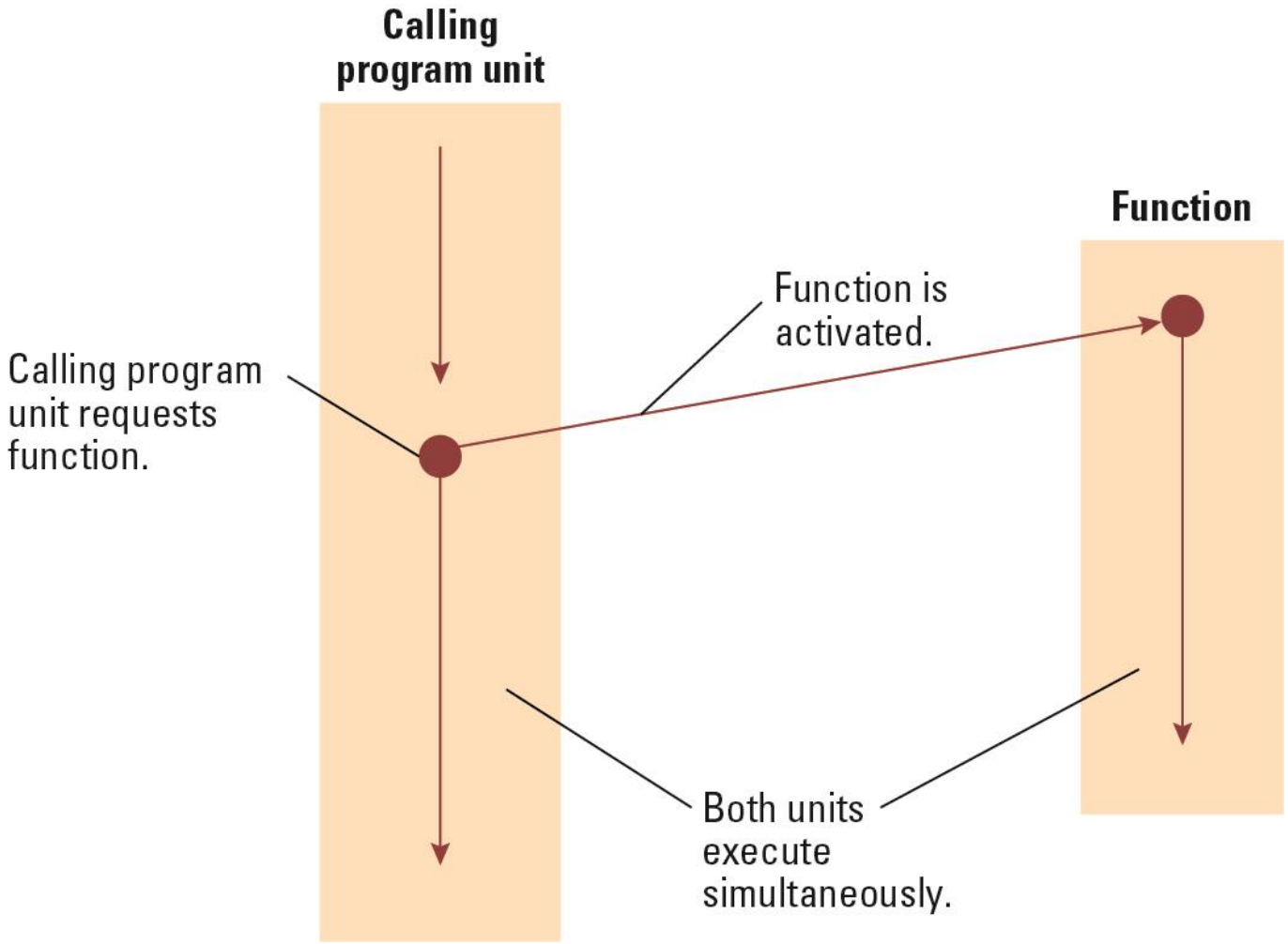
Additional Object-oriented Concepts

- **Inheritance:** Allows new classes to be defined in terms of previously defined classes
- **Polymorphism:** Allows method calls to be interpreted by the object that receives the call

6.6 Programming Concurrent Activities

- **Parallel** (or **concurrent**) **processing:** simultaneous execution of multiple processes
  - True concurrent processing requires multiple CPUs
  - Can be simulated using time-sharing with a single CPU

Figure 6.23 Spawning threads



Controlling Access to Data

- **Mutual Exclusion:** A method for ensuring that data can be accessed by only one process at a time
- **Monitor:** A data item augmented with the ability to control access to itself

6.7 Declarative Programming

- **Resolution:** Combining two or more statements to produce a new statement (that is a logical consequence of the originals).
  - Example: (P OR Q) AND (R OR ¬Q) resolves to (P OR R)
  - **Resolvent:** A new statement deduced by resolution
  - **Clause form:** A statement whose elementary components are connected by the Boolean operation OR
- **Unification:** Assigning a value to a variable so that two statements become "compatible."

Figure 6.24 Resolving the statements (*P* OR *Q*) and (*R* OR ¬*Q*) to produce (*P* OR *R*)

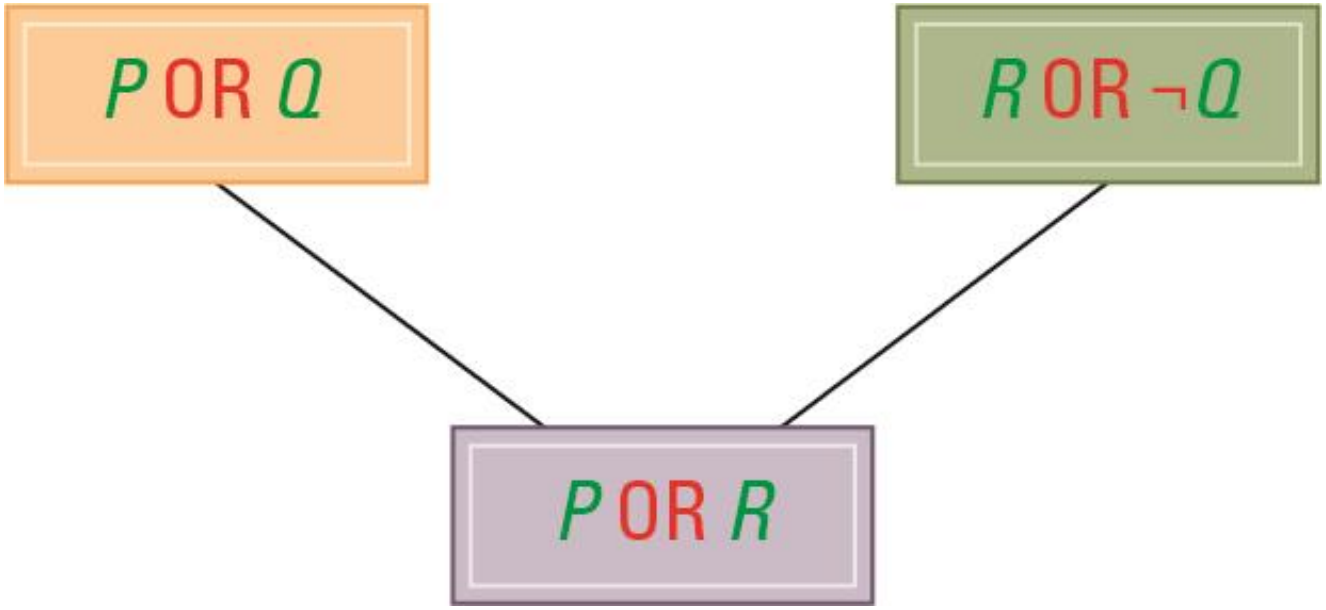
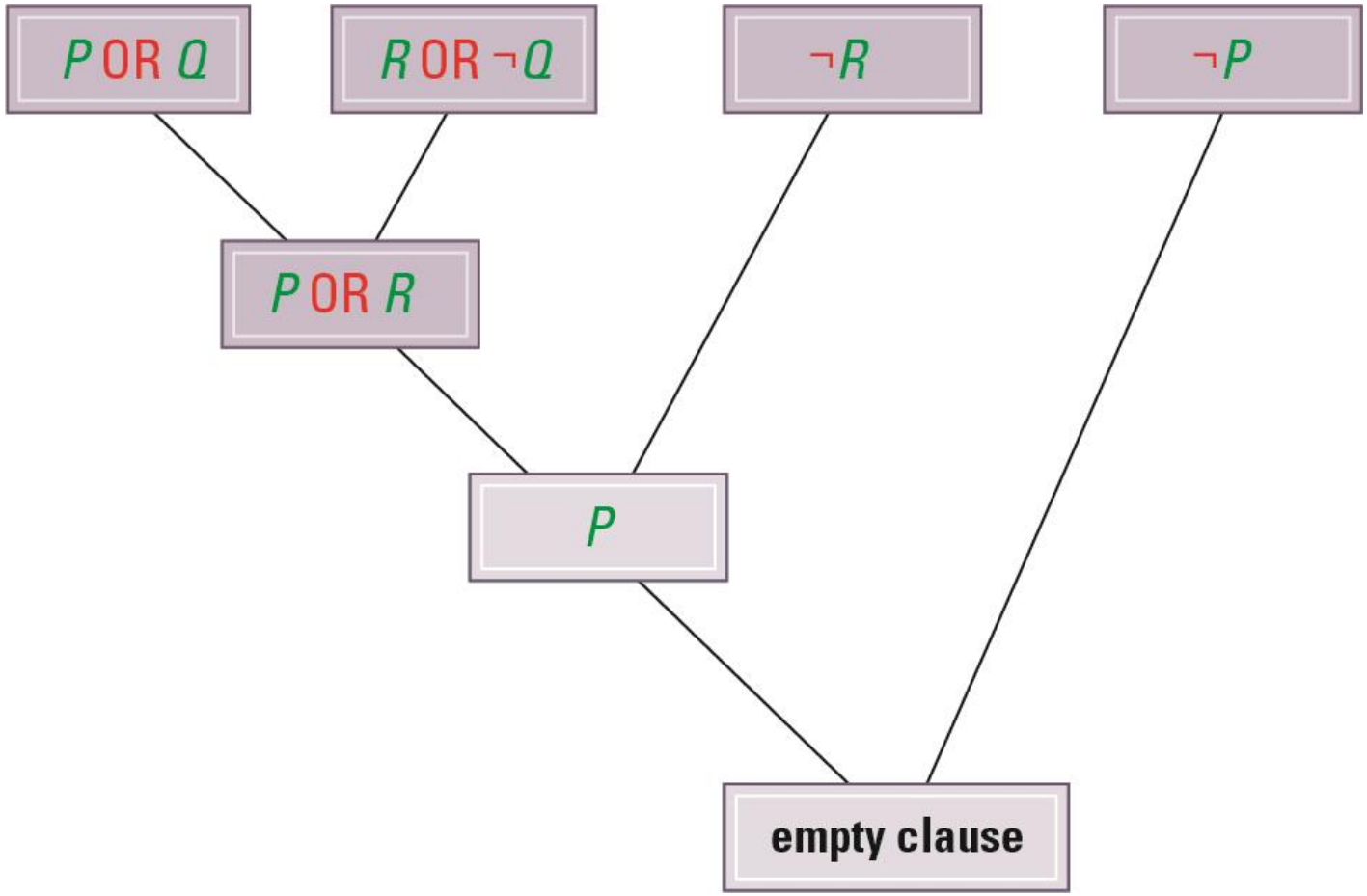


Figure 6.25 Resolving the statements (*P* OR *Q*), (*R* OR ¬*Q*), ¬R, and ¬*P*



Prolog

- **Fact:** A Prolog statement establishing a fact
  - Consists of a single predicate
  - Form: *predicateName*(*arguments*).
    - Example: `parent(bill, mary).`
- **Rule:** A Prolog statement establishing a general rule
  - Form: *conclusion* :- *premise.*
    - :- means “if”
  - Example: `wise(X) :- old(X).`
  - Example: `faster(X,Z) :- faster(X,Y), faster(Y,Z).`